

**A quantitative study investigating the effects of  
computerised clinical decision support in the  
emergency department**

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## **Abbreviations**

ACS	Acute coronary syndrome
ATS	Australian triage system
B&A	Before and after
BMA	British Medical Association
CAP	Community acquired pneumonia
CB&A	Controlled before and after
CCDSS	Computerised clinical decision support system
CDMS	Clinical document management system
CEM	College of Emergency Medicine
CfH	Connecting for health
CPOE	Computerised physician/provider order entry
CT	Computerised tomography
CTAS	Canadian triage acuity scale
CTPA	Computerised tomography pulmonary angiography
CVP	Central venous pressure
DH	Department of Health
ECA	Emergency Care Association
eCPG	Electronic clinical practice guideline
ECR	Electronic care record
ED	Emergency department
EDECS	Emergency department expert charting system

EPOC	Effective Practice and Organisation of Care
EPR	Electronic patient record
EWS	Early warning score
EWTD	European Working Time Directive
FBC	Full blood count
GMC	General Medical Council
HSCIC	Health and Social Care Information Centre
IT	Information technology
ITS	Interrupted time series
LOS	Length of stay
LV	Left ventricle
MMC	Modernising Medical Careers
MTS	Manchester triage system
NCEPOD	National confidential enquiry into patient outcome and death
NHS	National Health Service
NICE	National Institute for Health Care Excellence
NPfIT	National Programme for Information Technology
NRCT	Non-randomised controlled trials
PACS	Picture Archiving and Communication System
PAS	Patient administration system
QIPP	Quality innovation productivity and prevention
RCN	Royal College of Nursing

RCT	Randomised Controlled Trial
RN	Registered Nurse
SACT	Systemic anti-cancer therapy
UCLA	University of California Los Angeles

## **Definition of Terms**

**Computerised Clinical Decision Support System (CCDSS)** Interactive computer software designed to support clinician's health-related decision-making. It may provide prompts or reminders or advice based on the interpretation of patient specific data. Adapted from (Wyatt, J. & Spiegelhalter, 1991).

**Clinician** A generic term used to refer to a registered health care professional e.g. doctor, nurse

**Emergency Department (ED)** Within this thesis an ED refers to a department that provides a Consultant led service 24 hours a day and has full resuscitation facilities. Also referred to as a Type 1 department in the NHS (Health and Social Care Information Centre (HSCIC) (HSCIC, 2014).

**Emergency Triage** A term used within this thesis to describe the most common system of face-to-face triage in EDs in the UK. The nurse assesses the patient shortly after arrival and makes a decision about the urgency of the patient's problem and allocates a priority category.

**Minors stream** Patients allocated to this stream are ambulant, are able to wait in a waiting room and are unlikely to require any investigations other than a musculoskeletal x-ray

**Majors stream** Patients allocated to this stream require in-depth clinical examination often involving multiple investigations. They often require continuous assessment, monitoring and treatment e.g. cardiac monitoring, oxygen therapy, intravenous treatment.

**Manchester Triage System (MTS)** An algorithmic system using flow charts to identify clinical urgency and allocate a clinical priority in face-to-face triage situations (Mackway-Jones, Marsden , & Windle, 2006).

**eTriage** A bespoke CCDSS developed by the researcher to improve the accuracy of ED Triage decisions and increase the utilization of clinical guidelines.



## **Abstract**

*Introduction:* Over the last decade there has been a significant increase in the use of computerised clinical decision support systems (CCDSS) in health care. While significant research has been carried out to demonstrate the impact of CCDSS, the role of CCDSSs in Emergency Departments (EDs) remains under-investigated. The aim of this study was to investigate if the introduction of a CCDSS at ED triage, improved the quality and safety of decisions at triage and improved overall departmental safety.

*Methods:* This study adopted an interrupted time series design, with 8 time points. A random sample of triage records (n=400) from the year before the introduction of eTriage (four time points) were compared to the same number of records from the year after its introduction. Data was extracted from ED clinical records to establish the accuracy of triage prioritisation as an indicator of safety and the management of pain as an indicator of quality. A smaller subset of cases (n=44) over the same time period were analysed to assess any differences in the clinical management of patients presenting with neutropenic sepsis, a further indicator of safety. Logistic regression analysis was undertaken to expose the underlying decision-making trend over the whole study period.

*Results:* This study demonstrates a statistically significant improvement in triage prioritisation ( $p<0.001$ ), pain scoring ( $p<0.001$ ) and pain management ( $p<0.001$ ). Logistic regression demonstrated improvements in decision-making above what have been expected if eTriage had not been introduced. For patients presenting with neutropenic sepsis there was no statistically significant difference in their clinical management.

*Conclusion:* This study clearly demonstrated the positive impact that a CCDSS can have on the quality and safety for ED patients and provides a unique contribution of the current ED CCDSS knowledge base. The ever-increasing demand for emergency care and the difficulties in recruiting an experienced workforce is a fertile environment for clinicians to harness the potential that technological solutions can offer.

## **CHAPTER 1: INTRODUCTION TO THE THESIS**

### **1.1 Introduction**

This short introductory chapter gives an overview of the research undertaken for an award of Professional Doctorate. The background to the research and the drivers that culminated in the development of the research question, research aim and research objectives are briefly described. The local and national circumstances in emergency and urgent care in the United Kingdom (UK) at the time of the study are identified. It is these circumstances that inspired the development of a computerised triage system, hereafter known as eTriage. eTriage provides a local solution to the mismatch between rising patient attendances and available clinical resources. The remainder of this introduction touches briefly on the role of the practitioner researcher before outlining the content and layout of the thesis.

### **1.2 Background to the research**

This thesis presents a description of a quasi-experimental study that utilized an interrupted time series (ITS) design. In its broadest terms the study set out to investigate the assumption that a newly-developed computerised emergency department (ED) triage system provided consistently safer clinical decisions than the previous triage process. eTriage is the CCDSS that was developed by the researcher as a means of providing a more robust foundation for consistently safe clinical practice in ED. In 2008 eTriage began development, “in-house” by the researcher and a web developer from the Hospital Trust’s Information Technology (IT) department. It was launched in 2010.

The basis for the development of eTriage was to provide:

1. Computer decision-support for the triage process based on the Manchester Triage System (MTS) (Mackway-Jones et al., 2006)
2. Improved pain assessment and management at the point of triage

3. A direct link at the point of triage to the clinical guidelines that may be relevant to the patients' clinical presentation in ED.

The research described within this thesis evaluates these three aspects. Prior to the development of eTriage, triage nurses were trained using a standardised one-day training programme. Triage practice consisted of patient assessment and the allocation of a clinical priority by, in the most part, remembering the triage system taught during training. Training on the assessment and management of pain was via in-house training incorporating the College of Emergency Medicine (CEM) standards for pain assessment and management (CEM, 2010b, 2010c). The dissemination of ED clinical guidelines was through methods commonly used: posters, teaching sessions, educational materials, audit, email and web based access (Grimshaw, J., Thomas, MacLennan, Fraser, & Ramsay, 2004).

### **1.3 The research question**

Does the introduction of a computerised clinical decision-support system eTriage improve the quality of triage decisions and safety within the ED?

### **1.4 Research aim**

To test the researcher's assumption that computerised decision support at the point of triage is an effective means of improving the quality and safety of clinical care in ED.

### **1.5 Research objectives**

1. To compare the decision making of triage nurses before and after the introduction of eTriage
2. To compare the quality of pain assessment and management before and after the introduction of eTriage
3. To investigate the ability of eTriage to improve the care of patients with

potential neutropenia sepsis, a condition associated with significant morbidity and mortality

### **1.6 An overview of the study**

In this study, using a quantitative research method, data was extracted from ED records prior to the launch of eTriage and then one year after its introduction. The impact of eTriage on aspects of quality and safety were analysed using SPSS (20.0) by assessing the following primary and secondary outcome measures.

The primary outcome was concerned with the safety and quality of the triage decision-making process. This was judged by assessing the following:

- a) The accuracy of the triage prioritisation process
- b) The assessment of pain
- c) The appropriate management of any pain identified at triage

The secondary outcome measure was concerned with patient safety and assessed the management of patients that presented with possible neutropenic sepsis. Appropriate management was judged by assessing the following

- a) Triage priority allocated as “very urgent”
- b) Full blood count taken within one hour
- c) Timeliness of antibiotics

### **1.7 The research context**

There are huge challenges facing providers of emergency and urgent care in the UK. Ever increasing attendances and the current global economic crisis have created a situation where the demand for emergency health care cannot consistently be matched by the resources required to deliver it. The winter of 2012/13 saw the performance in EDs across the UK fall to levels not seen for over 10 years (Appleby, Humphreies, Thompson , & Galea, 2013). Whilst pressure is felt throughout the unscheduled care system the ED must continue to provide

care and treatment for ever-rising numbers of patients. As the recruitment of more staff to meet the rising demand became an increasingly less financially viable option, alternative solutions to support staff to deliver care were needed. CCDSSs have been shown to improve practitioner performance and a small number of studies are now demonstrating improvements in patient outcomes (Garg et al., 2005; Roshanov, P. et al., 2011a; Sahota et al., 2011). The development of eTriage was seen as a way to support the decision-making of ED staff as patient numbers increased and the need to deliver more efficient, more effective and more timely care became even more of an imperative.

There have been a myriad of service development initiatives in the National Health Service (NHS). Emergency and urgent care services have seen a significant number of these develop following the introduction of the first performance target in emergency care in 2001 (DH, 2001; Letham & Gray, 2012). The performance of EDs was measured against a standard that 98% of patients were seen, treated or discharged within 4 hours of arrival (DH, 2001). In order to achieve this improvement, changes to how care was organised and delivered within EDs and within the wider health economy took place. As there is pressure to move onto the next challenge, for many service developments, rigorous evaluation does not always take place. Clinicians and NHS managers often over-estimate the impact of changes, basing the evaluation on anecdote and their own firmly-held beliefs that they work (Elliott & Popay, 2000). Undertaking formal research on eTriage is seen as a means of thoroughly evaluating its impact and adding to what is already known about the role of CCDSSs in EDs. eTriage was a relatively small technological change but with the potential to revolutionise ED care if its assumed contribution to quality and safety was evident.

There has been an explosion in the number of studies evaluating the impact of CCDSSs over the last two decades (Haynes, 2011). As information technology advances, its use across all areas of health care has increased dramatically. A recent series of comprehensive systematic reviews has drawn the overall conclusions that CCDSSs can improve the process of care for some patients (Hemens et al., 2011; Nieuwlaat et al., 2011; Roshanov, P. et al., 2011a;

Roshanov, P. et al., 2011b; Sahota et al., 2011; Souza et al., 2011). However the number of studies that have demonstrated a positive impact on patient outcomes is relatively small and these are only of moderate quality (Roshanov, P. et al., 2011a). Relatively few studies have assessed the impact of CCDSSs in emergency or urgent care settings, (as will be seen in the literature review chapter, only one study was found that looked specifically at the use of a CCDSS in ED triage (Dong et al., 2005)). The current economic climate, coupled with the all year round pressure facing emergency care services, confirms that this research of great significance. Finding alternative, cost-effective solutions to meeting rising healthcare demand that have undergone rigorous evaluation is of critical importance. Before the recent economic downturn the answer to rising demand was to recruit more staff. However, the following influences have conspired to make this an unrealistic solution:

- There is currently a need to find £20bn in efficiency savings by the year 2015 (NHS Institute for Innovation and Improvement, n.d.).
- Changes in nursing and medical education have created a workforce with less experience and exposure to clinical learning opportunities than previously (House of Commons. Health Select Committee, 2008; Nursing and Midwifery Council, 2010).
- Inexperienced junior staff have been shown to order more tests and investigations than is required (even prior to changes in medical education (Dale, Green, Reid, Glucksman , & Higgs, 1995)).
- Emergency care as a career choice is less and less attractive especially to the medical profession. The speciality is facing its severest recruitment shortage at middle grade and consultant levels to date and this has a significant impact on departmental staffing. (Hassan, Walker, Harrison , & Rae, 2013).

### **1.8 Role of the practitioner as a researcher**

As the ED Nurse Consultant I was constantly frustrated by the failure of the usual clinical governance methods to ensure safe clinical care. No amount of training

and education, policy writing, guideline development or clinical audit seemed to be able to off-set all the other challenges faced by clinicians and detailed above; challenges that conspire against delivering safe, high quality care to patients in the ED. The concept of eTriage was borne out of a desire to ensure that situations one would class as a “never-event”, for example sending a patient home from ED with an ectopic pregnancy, did not occur. And importantly that these “never-events” ceased to occur regardless of the grade or experience of staff involved. eTriage was also seen as a way of ensuring that quality aspects of care, e.g. pain management, which were inconsistently assessed and treated, were improved. My role as practitioner researcher began before any concrete plans for research were developed. I developed the idea of eTriage in response to the failure of the established methods of clinical governance in being able to ensure consistently safe and effective practice. I worked with the IT department which developed the software for eTriage, I trained all the triage nurses and launched the system in ED in 2010. Following its launch I recognised the need to formally evaluate its impact and test the initial assumptions upon which it was developed; namely that care would be consistently safer and of a higher quality. A more in-depth analysis of my role as a practitioner researcher undertaking a professional doctorate is detailed in Chapter 7 of this thesis.

### **1.9 Structure of the thesis**

While this thesis has been written for the award of Professional Doctorate a more traditional Doctorate of Philosophy structure has been selected. Quantitative research, from a positivist paradigm separates data from beliefs and viewpoints. It is for this reason that reflections on the experience of practitioner research has not been woven into the main body of this thesis but dealt with separately chapter 7. This thesis contains eight chapters in total.

Chapter 1: Introduction to the Thesis - gives a brief synopsis of the thesis as a whole.

Chapter 2: Background and Context - gives a detailed overview to the background of the research and sets it within its clinical context. The origins of ED triage are

identified and how it is currently practiced is described. Clinical decision-making theories are briefly reviewed and consideration is given to decision making within the context of emergency triage. The triage decision-support software developed by the researcher eTriage is described in detail with the use of anonymised screenshots to enable a clear understanding of the CCDSS under investigation.

Chapter 3: Literature Review - critically analyses the evidence base for CCDSSs and their contribution to contemporary emergency care. Critical appraisal of CCDSSs used specifically in ED practice identifies the current knowledge base within this clinical setting. This enables a clear demonstration of what CCDSSs can contribute to clinical practice, quality and patient safety.

Chapter 4: Methods - begins with the research question to be answered, describes and justifies the research strategy, identifies the setting of the research, sampling approach and the data collection processes. Data analysis via SPSS (20.0) and the statistical processes used are explained and justified. Inter-rater reliability testing, ethics and research governance are also discussed.

Chapter 5: Results - presents the results of the statistical analysis.

Chapter 6: Discussion - provides a detailed discussion and critical analysis of the results. Comparisons are made with other similar studies and consideration given to what the results within this research contribute to current CCDSS knowledge. The limitations of the research are also discussed.

Chapter 7: Reflections on the role of practitioner researcher - provides a reflective critical commentary on the role of the practitioner researcher from the inception of eTriage to the present day. This chapter is written in the first person. Although the first person is not often used in quantitative research, the initial driver for this research was personal curiosity. Developing a deeper understanding of my role as a practitioner researcher during the research journey has been facilitated by writing in the first person.



Chapter 8: Conclusion and recommendations - draws final conclusions about the impact of this new knowledge, describes methods for dissemination and makes recommendations for further research.

## **CHAPTER 2: BACKGROUND AND CONTEXT**

### **2.1 Introduction**

This chapter analyses the various local and national influences that culminated in the development of eTriage. In particular it considers the effects of increasing emergency department attendances and the introduction of national performance targets on the provision of safe and effective emergency care. The challenges faced by EDs across the NHS in the winter of 2012/2013 are highlighted and the subsequent political debate that this downturn in performance created is discussed.

The provision of an effective emergency care workforce is considered in light of, changes to nursing and medical education over the last decade and the current economic climate. Against the economic backdrop of reducing budgets the NHS Quality and Safety agenda demands radical changes to the way organisations, departments and individual staff work. This quality agenda will be analysed and consideration given to its influence and impact on emergency care. The NHS IT strategy will be highlighted and more specifically the contribution of CCDSSs to quality and safety will be described.

The origin of triage and its international development in EDs is described. Clinical decision-making theories are considered within the context of Triage practice and emergency care. Finally, eTriage is the intervention under investigation in this research and it is described in detail for the reader.

It is the culmination of all the aforementioned influences that create a perfect clinical environment for the development and evaluation of CCDSSs in Emergency Care areas. They are illustrated in Figure 2.1 and are addressed in this chapter.

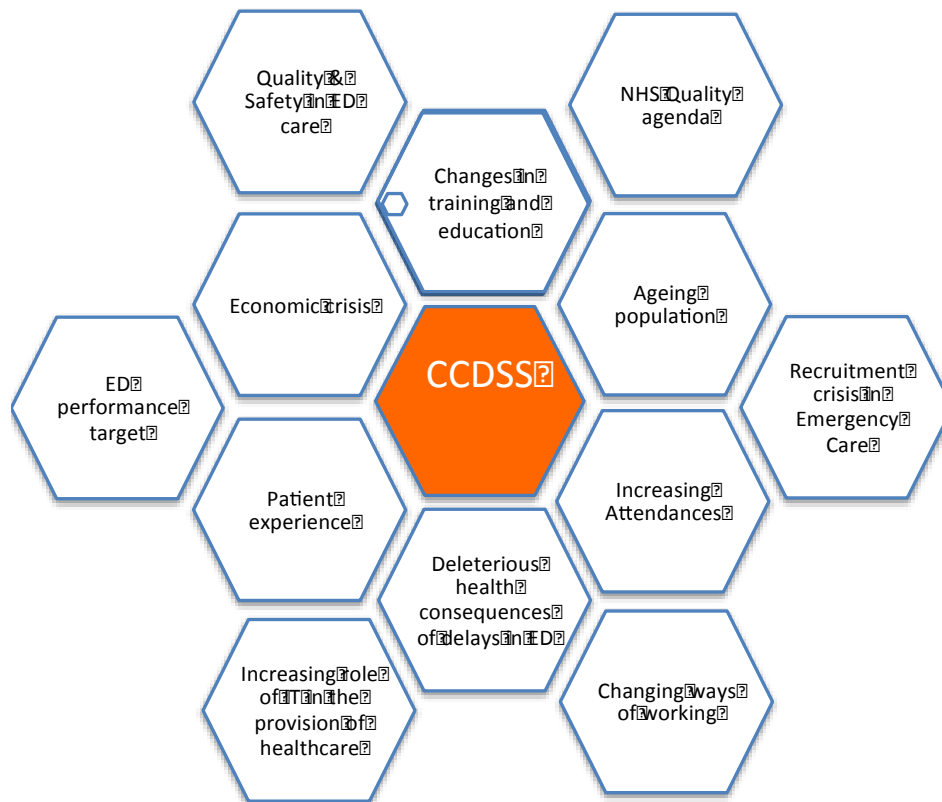


Figure 2.1 Contemporary influences in the NHS that create an ideal platform for establishing the contribution the CCDSS can make to emergency care

## 2.2 Politics and contemporary healthcare

The UK Labour Government is credited with the creation of the NHS in 1948. Despite several legislative changes over the last 65 years, its guiding principle of free health care for all has remained its foundation. In 1997 after a conservative government for 18 years Labour was in power again, led by Prime Minister Tony Blair. This Blair ministry saw a decade of economic growth, which contributed to significant investments in the NHS during this time. NHS reforms created a performance driven culture that had not been seen before with the introduction of “targets” across many areas in health care (Kings Fund, n.d.). Targets were introduced for various reasons, for example to reduce the amount of time patients waited for out-patient appointments and to ensure there were not long delays or multiple cancellations for surgery. This performance culture was seen as a way of driving up standards and ensuring that patients received timely care. No

area of healthcare was exempt from the effects of this new target driven approach. The rationale for, and impact of, national performance targets for emergency care will now be considered.

### **2.3 Emergency care 2000-2012**

In 2001 a specific performance standard was set for patients attending various Emergency Care services (DH, 2001). Reforming Emergency Care (DH, 2001) was the single most influential document to change the way emergency and urgent care has been delivered since the inception of the NHS. It mandated that by December 2004 98% of patients attending EDs had to be seen, treated or discharged within 4 hours. At that time ED patients were often waiting in excess of 12hrs to be admitted to an inpatient bed (Cooke, M. et al., 2004). The impact that long delays in ED have on mortality and morbidity is significant. In addition there is international evidence on the negative health consequences of long waiting times in ED (Trzeciak & Rivers, 2003; Cooke, M. et al., 2004; Guttman, Schull, Vermeulen, & Stukel, 2011; Higginson, 2012). There is a direct correlation between a delay in admission from ED to an inpatient bed and an increase in overall length of hospital stay (Singer, Thode, Viccellio, & Pines, 2011). Patients who have a wait greater than two hours from the decision to admit have an increase in mortality directly related to their wait, even when co-morbidities are controlled for (Singer et al., 2011). The condition specific evidence that has emerged in the last decade regarding the adverse effects of waiting for admission in ED is significant. Time critical interventions, for example analgesia for severe pain, intravenous antibiotics for community acquired pneumonia and thrombolysis for myocardial infarction are delayed (Schull, Vermeulen, Slaughter, Morrison, & Daly, 2004; Pines, J. M. et al., 2007; Pines, J. M. & Hollander, 2008). Other risks are also introduced when patients are delayed in ED and there is overcrowding. Medication errors are more frequent and pneumonia in intubated trauma patients is more likely to occur (Carr et al., 2007; Kulstad, Sikka, Sweis, Kelley, & Rzechula, 2010).

In the UK overcrowding in EDs became a significant issue in the late 1990s (Cooke, M. et al., 2004). However, the clinical consequences described above were not evident until much later. What was known and very clear to politicians was that patients did not want to wait. Rapid access to care with a minimum wait has been of primary importance to patients for over twenty years (Hunt, M. T. & Glucksmann, 1991; Picker Institute, 2012). Long waiting times have been and continue to be significant cause of dissatisfaction to patients (Booth, Harrison, Gardener, & Gray, 1992; Trout, Magnusson, & Hedges, 2000; Pines, J. et al., 2008; Parker & Marco, 2014). There is clear clinical justification for reducing the amount of time patients wait in EDs. Equally, patients' report that they are dissatisfied with long waiting time in EDs and elsewhere in the NHS. The approaches that were used by EDs to reduce waiting times and achieve the national performance standard will now be discussed.

### *2.3.1 Reforming emergency care 2001*

It became a political imperative to reduce waiting times in EDs. In order to support Reforming Emergency Care (DH, 2001) there was significant investment in emergency services at the time. One hundred and eighty three more Emergency Medicine Consultants and 600 more Emergency Nurses were recruited to ensure that services had adequate staffing (DH, 2001). Various strategies were developed to reduce waiting times and achieve the desired levels of performance. Across the UK emergency nurses developed more autonomy, emergency nurse practitioners ran minor injury units or managed patients with minor injuries in emergency departments (Cooke, M. et al., 2004). Advanced practitioners developed skills to independently manage patients with major presentations and the emergency care workforce changed considerably in order to meet the ever-increasing demand (Letham & Gray, 2012). Different models of care saw patients managed in different areas of an emergency department by different teams of staff. This process, called streaming often involved a "see and treat" process whereby patients with more minor problems were seen and treated shortly after arrival (O'Brien, Williams, Blondell, & Jelinek, 2006). All these strategies were employed to drive down waiting times and were facilitated

by the “Emergency Services Collaborative” (DH, 2007). The Emergency Services Collaborative was a national programme which ran from October 2003 to October 2004. In six waves it covered all 200 EDs in England and introduced evidence concerning the factors that reduced waits. Together with improvement methodologies Trusts began to see more patients managed within 4 hours. From 2004 Reforming Emergency Care led to significant reductions in waiting times in EDs (DH, 2004). The introduction of a performance target for UK EDs forced organisations to invest in services and introduce new ways of working. As a consequence of this, delays in EDs were reduced. Initially a subtle change to the target took place in 2010 followed by the introduction of a set of measures for EDs; these will be examined in the next section.

### *2.3.2 Changing performance targets and the introduction of quality indicators in 2010*

In June 2010 the Secretary of State for Health of the incoming coalition government reduced the ED performance target from 98% to 95% (Letham & Gray, 2012). This was in response to clinicians who were concerned that a 2% margin did not take into account the number of patients with on-going resuscitation needs. Interestingly as soon as this change was made the average number of patients waiting less than four hours fell to 95% instantly (Woodcock, Poots , & Bell, 2012). Later in 2010 the Department of Health published new clinical quality indicators for all EDs, to be implemented by April 2011 (DH, 2010a). This new approach, as well as considering length of time spent in ED also addressed other areas of care. It acknowledged that safe care of high quality could not be assured by only focusing on “time spent in ED” alone. Additional measures provided other evidence of the impact of care delivered in ED and for the first time there was an emphasis on the emergency care patient’s experience. These new quality indicators set minimum standards that would encourage a culture of continuous improvement see Table 2.1 below. The combination of eight standards aimed to ensure three things: 1) the best health outcomes with minimal risk 2) care that is timely and in the best location and 3) care was correct the first time (DH, 2010a).

Table 2.1 A&E clinical quality indicators (DH, 2010a)

1.	<b>Ambulatory Care.</b> To reduce avoidable hospital admissions by improving the provision of ambulatory care.
2.	<b>Unplanned re-attendance rate.</b> To reduce avoidable re-attendances at A&E by improving the care and communication delivered during the first attendance.
3.	<b>Total time Spent in the A&amp;E Department.</b> To improve the timeliness and monitoring of care to ensure patients do not have excessive waits in A&E before leaving the department.
4.	<b>Left without being seen.</b> To improve patient experience and reduce the clinical risk to patients with high-risk conditions who leave A&E before receiving the care they need.
5.	<b>Service Experience.</b> To improve the experience of patients who use A&E services and their carers.
6.	<b>Time to initial assessment.</b> To reduce the clinical risk associated with the time the patient spends unassessed in A&E. This assessment must include an early warning score and pain score.
7.	<b>Time to Treatment.</b> To reduce the clinical risk and discomfort associated with the time the patient spends before their treatment begins in A&E.
8.	<b>Consultant Sign-off.</b> To improve clinical processes and outcomes and reduce the risk patients are exposed to.

The four hour ED performance target was introduced as a means of reducing exorbitantly long waiting time in EDs that had developed during the 1990s (DH, 2001). It was introduced by the then Labour government and was part of its strategy to rebuild the NHS (Letham & Gray, 2012). However there is no published evidence that identifies that 4 hours is in fact the “correct” amount of time for assessment, investigation and the development of a treatment plan in an emergency or urgent care setting. Where 4 hours as opposed to 3.5 hours or 6 hours came from is not identified in the literature or justified in any of the government documents. With an increasingly older population management “within four hours’ can be very difficult due to complex medical problems and comorbidities (Dawood, Dobson, & Banerjee, 2011). The introduction of the four-hour performance target has created a significant degree of debate and disagreement within the literature (Appleby et al., 2005; Bevan & Hood, 2006; Lilford, Brown, & Nicholl, 2007; Kelman & Friedman, 2009; Weber, Mason,

Freeman , & Coster, 2012). A recent systematic review of the impact of the four-hour performance target identified that the financial investment of £820 million between 1998-2007 did not consistently improve care across the NHS or reduce mortality (Jones, P. & Schimanski, 2010). What is evident within the national ED attendance data is a sharp increase in patients attending EDs from 2004 (Appleby et al., 2013). This coincides with GPs opting out of out-of-hours care (UK Government, 2004). The relationship between improved ED waiting times and increasing attendances that continued into the next decade will be explored further in the next section.

## **2.4 Increasing emergency department attendances**

There are now 7.5 million more ED attendances in the UK than there were 10 years ago (Kings Fund, 2013). However this 50% increase has been identified by some agencies as being due mainly to rises in the number of patients attending walk-in centres and minor injury units and not major EDs (Kings Fund, 2013). Due to a change in how the data was collected from 2004, minor injury units and walk-in centre attendances were added to the national ED attendance dataset (Appleby et al., 2013). Minor injury units and walk-in centres were developed during the 2000s as a means of managing demand, reducing ED attendances and providing quick access to a clinician (Salisbury, 2003). They are usually located in town or city centres and provide assessment, advice and treatment for minor injuries and ailments. Minor injury units and walk-in centres are not open 24hrs a day and do not manage the whole range of emergency/urgent presentations. If for example a patient attended with chest pain they would receive a brief assessment and then be transferred to a major ED. CEM (2013b) report evidence from a survey of 131 EDs which all identify that their attendances are continuing to rise. These rises are independent of those attendances at other emergency care facilities such as walk in centres. There appears to be conflicting data about the nature of rises in ED attendance. However, the annual attendances in the department involved in this study have risen in line with national trends (HSCIC, n.d.). These rises are independent of any additional figures for walk-in centres and minor injury units. See Table 2.2 of attendances below



Table 2.2 ED attendances – data extracted from Health and Social Care Information Centre (n.d.)

<b>Year</b>	<b>Attendances</b>	<b>Annual rise</b>	<b>Percentage change</b>
2013	87,969	-2112	-2.3%
2012	90,081	4,673	5.5%
2011	85,408	-30	-0.03%
2010	85,834	2,568	3.1%
2009	83,266	2,618	3.2%
2008	80,648		
Total increases over 6 year period		7,321	8.3%

These increases equate to an extra 26 patients per day in 2012 than five years previously and 20 extra patients per day in 2013. What these figures do not account for is the patient acuity. Managing 20-26 extra patients per day with a minor problem is relatively easy. Managing an extra 20-26 patients per day, with complex problems, requiring lengthy investigations, speciality referral and inpatient admission, is much more challenging. Without the appropriate additional staffing resources meeting increased demand in a robust way is not achievable (CEM, 2013b). The substantial fall in ED performance during the winter of 2012/13 is now considered in detail as national interest and political debate was significant during this time.

## **2.5 UK emergency department performance in 2013**

In early 2013 UK ED performance took a significant downward turn. Performance between January-March 2013 was the worst it had been since the 98% operational standard had been introduced in 2001. There was no doubt that over this time EDs were struggling to meet demand. This was highlighted in the media and by the key UK professional bodies representing emergency care clinicians, the College of Emergency Medicine (CEM) and the Royal College of Nursing (RCN) (Keogh, K., 2013b). A House of Commons Health Select Committee was convened during the summer of 2013 and heard evidence from CEM regarding the current crisis in EDs in England. Evidence was presented of the overwhelming demand as patient numbers and acuity increased and the inability to recruit a suitably trained clinician workforce (Health Select Committee, 2013a). The use of locum

doctors has increased dramatically in the NHS to support a whole range of services (Royal College of Surgeons, n.d.). The cost of hiring locum doctors in the NHS in England for the period 2009/10 was over £¼ billion. This is a staggering increase of £¼ billion on the year before (Royal College of Surgeons, 2010). In Emergency Care the use of locum doctors is proportionately high with reports that one fifth of medical staffing at weekends is by locums (O'Dowd, 2013). The average annual spend on locum doctors per ED is £500,000 (Health Select Committee, 2013b). Locum doctors will not know the EDs policies or clinical guidelines and often require a level of support and supervision, adding to the pressure within the system (General Medical Council, 2013). In addition to these challenges the provision of telephone advice regarding access to healthcare changed. The consequences of this change will now be discussed.

#### *2.5.1 The introduction of NHS 111*

The introduction of NHS 111 during 2013 caused significant problems in some parts of the UK (BBC News, 2013a). NHS 111 is a free non-emergency number for use in England when a member of the public feels they or their relative needs urgent healthcare that is not life-threatening and does not warrant an immediate “999” ambulance (NHS Choices, 2013). NHS 111 replaced the previous NHS helpline called NHS Direct to focus more specifically on giving advice to the public on how to access emergency services, whereas NHS Direct gave a range of health advice. In many areas in the UK the local out-of-hours provider assessed over the telephone requests for urgent access to healthcare and directed patients to the most appropriate place; these services were also stopped and replaced by NHS 111 (BBC News, 2013b). The British Medical Association (BMA) which represents 150,000 UK Doctors had extensive concerns about the implementation of NHS 111 and wrote the Secretary of State for Health outlining them in February 2013. The BMA asked for the rushed implementation to be delayed so that further assurances about the quality, safety and capacity with the system could be assessed (British Medical Association, 2013a). There is startling evidence from Greater Manchester in April 2013 that when NHS 111 replaced the previous out-of-hours triage systems patients waited hours after giving their basic

demographic details to be called back by someone who would assess the urgency of their problem (British Medical Association, 2013b). This culminated in a large increase in the number of ambulance requested during this time and subsequent ED attendances (Manchester Evening News, 2013).

So far this chapter has considered the introduction of performance targets in the NHS and their impact on waiting times in ED. Changes in the provision of out-of-hours care by GPs and the introduction of NHS 111 is considered by some to have played a part in the increasing patient attendance to ED. Improving the way that care is delivered, meeting demand and introducing new ways to access healthcare e.g. minor injury units are likely to explain in some part the public's apparent preference for ED care. The next sections explore the consequences of changes to healthcare education together with the economic downturn in the late 2000s and an increasingly older population.

## **2.6 UK education and training of health care professionals**

From 2005 there was a significant change in medical education in the UK called Modernising Medical Careers (MMC) (DH, 2005). It aimed to reform medical training and was seen as a means of delivering an NHS plan target of increasing the number of hospital consultants (DH, 2000). There was a complete overhaul of junior doctor training and part of the change was to shorten the time it took to reach a consultant grade (DH, 2005). Another element of MMC was to ensure doctors in training abided by European Working Time Directive (EWTD) legislation so that they did not have a working week that exceeded 48 hours (NHS Employers, n.d.). MMC reduced the time it took to train a junior doctor within any given specialty by on average 1 year. However exposure to the widest range of clinical scenarios and surgical techniques was also significantly reduced by shortening the working week, for some specialties by up to two thirds (DH, 2005). Both these scenarios culminated in creating a medical workforce that had less experience in both number of hours per week and length of time in each speciality (Croft & Mason 2007). Inexperienced junior doctors in emergency care settings continued to add pressure to an already stretched system (Armstrong,

White & Thakore 2010). They came with less experience and gained less whilst on a shorter placement. Their decision-making took longer; they requested more investigations and often made more referrals to inpatient specialities (Armstrong, White & Thakore 2008). A review of the impact of the EWTD on doctors training recommended that part of the solution to improved training and supervision was a consultant delivered service (Temple, 2010). There is strong evidence that a consultant delivered service improves patient outcomes and patient satisfaction and can also contribute to efficiency savings (Geelhoed & Geelhoed, 2008; McNeill, Brahmabhatt, Prevost, & Trepte, 2009; White, Armstrong, & Thakore, 2010). However, with the current problems in recruiting ED Consultants across the whole NHS this does not seem to be an imminent solution. Prior to the changes in medical education, nurse training had already seen a major transition from a clinical, practically focused curriculum to an academic one.

#### *2.6.1 UK nurse education*

In 2000 nurse education was reformed. This followed the recommendations in *Making a Difference: Strengthening the Nursing, Midwifery & Health Visiting Contribution to Healthcare* (DH, 1999). Nurse education moved from schools of nursing based within hospitals into Universities. There was a conscious effort to remove the “handmaiden” connotation associated with nursing and its subservient role to medicine. Instead there was the introduction of a strong academic base that informs clinical decisions and ensures that the nurse is an equal member of the care team (United Kingdom Central Council for Nursing Midwifery and Health Visiting, 1986). However the increase in academic content meant a reduced focus on the development of practical skills. There was much criticism as the practitioners produced by this new training were not seen as confident in practice. Nor were they viewed as having the requisite clinical skills required for the registered nurse (Lord, 2002). Both of the changes in nursing and medical education added to the pressure already felt in EDs across the UK. Patient attendance was continuing to rise yet the workforce was less prepared in terms of experience and clinical skills to meet the increasing demands. In addition to these

changes an economic recession began in 2008. The effects on healthcare have been widespread and are likely to continue. These will now be outlined

## **2.7 Current economic healthcare climate 2008-2014.**

Within the current health care climate the need for cost-effective, efficient and safe care has never been more paramount. Due to massive deficits in the country's economy the current freeze in public spending means, in real terms, significant cuts to NHS budgets over the next three to five years. Termed the "Nicholson Challenge" Sir David Nicholson the NHS Chief Executive has challenged the NHS to make between £15-20 billion efficiency savings by 2014. The relentless demand on emergency and urgent care services over the last decade has seen the average annual ED attendance rise from 14 million in 1993-2002 to 19 million in 2008 and over 20 million in 2011 (DH, n.d.-b). This increase in attendances would previously have been funded by the local Primary Care Trust. However with the shortfalls in NHS budgets any annual increase in activity is receiving only 30% of the national tariff and there is no further payment for any additional activity (DH, 2010c). Previously when increased activity generated increased revenue for NHS Trusts organisations could grow and develop their services to meet demand. However, the current state of the economy has created an unprecedented situation; health services must continue to improve quality, meet increasing demands but at the same time reduce costs. The challenge for ED clinicians and NHS managers is to find alternative and/or more efficient means of providing ED care that is safe and effective. Before examining quality and safety in the NHS it is vital to consider the effect of an increasingly older population. Older people are significant users of emergency services and the complex nature of their medical problems makes acute care provision increasingly difficult.

### ***2.7.1 The ageing population***

The number of people over the age of 85 years has increased in the UK by 20% since 2006 (Appleby et al., 2013) and is expected to continue to increase over the next 20 years by two-thirds (Wanless, 2006). Between 2009-2010 15% of ED attendances were over 70 and this increase will continue (HSCIC, 2011). An ageing

population adds to the increase in demand for EDs and subsequently hospital admission. Compared to patients of less than 30 years, those over 70 years are five times more likely to be admitted (George, Jell , & Todd, 2006). Older people have unique care needs that can be difficult to meet in a busy emergency care environment (Dawood et al., 2011). Older people spend more time in ED, their problems are more complex, they undergo more investigations and often require critical care (George et al., 2006). The next section addresses issue of quality and safety in health care, both large scale across the NHS and then more specifically within EDs.

## **2.8 NHS quality agenda**

Quality has always been a priority in the NHS; in the most recent large scale review of the NHS the emphasis has been even more prominent (Darzi, 2008). Lord Darzi describes a health service of the future where variations in quality are abolished. The over-riding principle within the review is that quality is central to everything in the NHS; clinical care is always effective, safe and personal. The challenges faced in 2014 and beyond are varied and great. The need for cost-effective, efficient and safe care is an imperative. A white paper by the new coalition government in England has continued with the overriding objective of making healthcare safer, more effective and centred around the patient (DH, 2010b). The changes that need to be made to health care services in order to deliver high quality and efficiency is supported by the Quality Innovation Productivity and Prevention (QIPP) programme (Smith, S., 2012). QIPP is about wide-ranging strategies across the NHS rather than a single policy about the delivery of healthcare. It is the way in which the health service will be supported to make £20 billion worth of savings, manage increasing demand and improve quality. In April 2013 NHS Improving Quality was created to continue the QIPP initiative and drive improvement across all the areas in the NHS Outcomes Framework (NHS Improving Quality, n.d.). The focus of the NHS under a coalition government was concerned with quality and safety and a greater emphasis was placed on patient satisfaction. The recently formed NHS England claims to be taking a new approach to deliver all the current challenges (NHS England, 2014a)

NHS England has at its core the improvement of health outcomes for people in England (NHS England, 2014a). Its definition of quality is composed of three inter-related parts:

- Care that is **clinically effective** – not just in the eyes of clinicians but in the eyes of patient themselves
- Care that is **safe**
- Care that provides as positive an **experience** for patients as possible

(NHS England, 2014b).

This definition encompasses the primary role and function of NHS England and the NHS Clinical Commissioning Groups across England (NHS England, 2014b). It also incorporates all the elements from the preceding NHS reviews and White papers which focused on a new drive to ensure that care that was safe, personal, effective and patient centred (Darzi, 2008; DH, 2010b)

#### *2.8.1 Professional perspectives – quality & safety.*

The quality of NHS care is an issue of paramount importance to all grades of staff that work in the NHS. Issues about the quality of care in NHS hospitals have been brought to the attention of the whole world through several recent highly influential reports namely The Francis Report (Francis, 2013) and the Berwick Report (National Advisory Group on the Safety of Patients in England, 2013). The Francis Report highlighted whole system failure in the care of hundreds of patients at Mid Staffordshire NHS Foundation Trust. It identified an environment where the pressure to achieve targets became the overriding priority, creating a culture of uncaring and bullying behaviours where poor standards were tolerated and denied (Francis, 2013). There is explicit mention in this report about failures in the provision of quality emergency care. Specific issues that were identified are listed below:

- Bullying and harassment of nursing staff regarding ED performance

- Poor quality
- Lack of senior nurse leadership
- Managerial pressures on junior staff
- Dangerous use of the admissions unit to avoid patients staying in ED more than four hours
- Poorly managed transfers of patients from ED
- Unsafe qualified nurse staffing levels
- Disempowerment of staff
- Insufficient numbers of ED Consultants.

In response to this report the Government commissioned the Berwick Report into patient safety in the NHS (National Advisory Group on the Safety of Patients in England, 2013). Don Berwick made ten recommendations to improve safety in the NHS, putting quality and patient care at the heart of everything that is done. Further prominent reports have followed Francis with far-reaching recommendations on patient mortality, nurse staffing, patient complaints systems and the role of support workers in health & social care (Cavendish, 2013; Clwyd & Hart, 2013; Cummings, 2013; Keogh, B., 2013a). The UK government response to the Francis Report was published in November 2013 with commitments to safer staffing, patient safety, better complaints processes, new criminal offences and improvements for support workers (DH, 2013b, 2013a). All these reports have culminated in increasing the spotlight on quality and safety in the NHS as never seen before. Whilst these reports are far-reaching and mean significant changes to the structure, function and culture of all NHS organisations they also have relevance at an individual, departmental and specialty level. Providers of emergency care will be able to utilize the opportunities that these new ways of thinking bring to develop services that are more responsive and clinically led.



### *2.8.2 Quality and safety in the emergency department*

The A&E Quality Indicators launched by the DH in 2010 identified standards of care that if consistently achieved would signal that care was of high quality (DH, 2010a). In addition to measures of timeliness emphasis was also placed on where care was delivered, the management of clinical risk, patient experience and the review of certain patient groups by senior clinicians (DH, 2010a). CEM has set numerous standards for the delivery of high quality emergency care (CEM, 2013a). The majority of these standards relate to specific medical problems encountered in emergency care e.g. paracetamol overdose (CEM, 2013a). Many can be used by nursing as well as medical staff, for example pain management guidance (CEM, 2010b, 2010c). Within the UK the Emergency Care Association (ECA) represents the interests of emergency nurses who are members of the RCN and they contribute to joint guidelines with CEM; for example a recent triage position statement was jointly developed (CEM, 2011). As well as setting numerous clinical quality standards CEM also identifies safety principles for EDs and provides toolkits for benchmarking safety (CEM, n.d.). The ECA does not identify emergency nursing quality or safety standards and the DH A&E Quality Indicators (DH, 2010a) do not specifically relate to the contribution of emergency nurses. To address this gap a suite of emergency nursing quality indicators have been developed in the UK and are used in several departments to benchmark the quality of nursing care (Bennett, 2012). These nursing quality indicators are listed in Table 2.3.

Table 2.3 Emergency nursing quality indicators (Bennett, 2012)

1.	Early warning scoring
2.	Paediatric early warning scoring
3.	Weight assessment in children
4.	Pain assessment and management
5.	Communication
6.	Transfer/Discharge
7.	Timeliness
8.	Safety
9.	Infection prevention
10.	Privacy, dignity & nutrition

#### *2.8.3 National reports regarding patient safety in ED*

Despite the numerous markers of quality and safety in emergency care there are areas of care that have been highlighted as needing improvement in national reports (Mort, Lansdown, Smith, Protopapa , & Mason, 2008; Centre for Maternal and Child Enquires, 2011; Parliamentary Health Service Ombudsman, 2013). Some have focused on less common conditions but that have life-threatening consequences if poorly managed initially such as neutropenic sepsis (Mort et al., 2008). Neutropenia (reduction in neutrophils) occurs as a result of chemotherapy induced bone marrow suppression rendering the patient susceptible to opportunistic infection. Without an adequate immune response the progression from initial infection to overwhelming sepsis can be rapid, insidious and fatal (Livingston, Craike , & Considine, 2011). The Parliamentary Health Service Ombudsman highlighted poor initial care of patients presenting with sepsis which claims over 37,000 lives in the UK each year (Parliamentary and Health Service Ombudsman 2013). These reports continually prompted the clinicians to consider ways of improving the care of these patients in the ED (CEM, 2013a, 2013b). The care of patients with potential neutropenic sepsis has been particularly challenging and shares similar problems to the care of patients with general

sepsis symptoms. However, because this group of patients have a significantly compromised immunity, sepsis has a substantially increased effect on morality and morbidity (National Chemotherapy Advisory Group, 2009).

#### *2.8.4 Pain and neutropenic sepsis as markers of quality and safety*

Despite clear standards about how and when care should be delivered there are still significant shortfalls between the standards that are set and the care that patients receive (CEM, 2013a). The research with this thesis aims to identify if a triage CCDSS can address these shortfalls.

Patients presenting to ED with potential neutropenic sepsis are of particular interest to this research. Sepsis in patients with neutropenia is often fatal if not treated promptly (Herbst et al., 2009), they present infrequently to district general hospitals (Mort et al., 2008) and a feature within a CCDSS to improve their care was felt to have real potential. A National Enquiry into Patient Outcome and Death (NCEPOD) (Mort et al., 2008) reviewed the care of patients who died within 30 days of chemotherapy and identified the following contributory factors

- Failure of junior doctors to make the diagnosis
- Lack of early assessment by junior medical staff
- Delay in admission to hospital
- Unacceptable delay in resuscitation
- Unacceptable delay in prescribing antibiotics – 4 hours
- Unacceptable delay in administration of antibiotics – 12 hours after prescription written
- Unacceptable delay in senior staff review
- Unacceptable delay in transfer to intensive care
- Different antibiotics used to those stated in local policy

- Lack of staff awareness that patients may not always have a fever with neutropenic sepsis.

(Mort et al., 2008)

All of these reveal the potential for errors in an emergency department setting due to a predominantly junior and or inexperienced workforce, especially at evenings and weekends (Dr Foster Intelligence, n.d.).

The management of pain is a well-established quality standard in emergency care for adults and children (CEM, 2010b, 2010c; Bennett, 2012). Over 75% of patients that present to an ED have a painful element to their condition (Body & Foex, 2012). Despite these factors there is persistent evidence that pain is not always assessed and if it is it is not always adequately managed (Todd et al., 2007; Lee, G., Smith, & Jennings, 2008; van der Wulp et al., 2011). In order to establish the impact of a triage CCDSS on quality and safety the care of patients in pain and those with potential neutropenic sepsis will be evaluated. More detailed rationale for the selection of these two clinical areas will be identified in chapter 4. The following section will discuss the use of IT in the NHS. In more global terms the strategy for the development of IT in the NHS will be examined and then more specifically the role of CCDSSs will be explored.

## **2.9 Information technology in the NHS**

During the last decade the development of the national infrastructure for IT within the NHS has been fraught with difficulties. NHS Connecting for Health (CFH) was formed in 2005 and was responsible for the delivery of the National Programme for IT (NPfIT) (DH, n.d.-c). The aim of NPfIT was to develop an electronic care record (ECR) accessible by patients and staff. Complete connectivity was planned so that 30,000 GPs and 300 hospitals had secure, auditable access to the ECR (DH, n.d.-c). CFH failed to deliver the proposed ECR and failed to meet the expectations of clinical staff within the established timeframe. The NPfIT was fraught with difficulties from the outset including: contractual problems, withdrawal of IT providers, connectivity issues and costs

escalating by >700% (National Audit Office, 2006; Public Accounts Committee, 2009, 2011). CFH ceased to exist in 2013 and the Health and Social Care Information Centre (HSCIC) became responsible for the delivery of some of the CFH projects. Despite the failure for CFH to develop an ECR there were some successful IT developments with the NHS such as: NHS mail and the Picture Archiving and Communication System (PACS). NHS mail is a national email and directory service for use by all NHS staff. Its significant security allows the safe transfer of confidential patient information (DH, n.d.-d). PACS provides electronic storage and access to radiological digital images for example x-rays and computerised tomography (CT) scans (DH, n.d.-c). It has demonstrated significant improvements for both patients and clinicians in terms of ease of access, ease of use, improved imagery and improved diagnostic methods (DH, n.d.-e).

The current DH framework for IT in the NHS was published in 2012 and sets the strategic direction via a 10 year framework to increase IT use and in doing so, to also improve patient care and health outcomes (DH, 2012). It identifies that a more joined NHS will be safer and have benefits for: patients, carers, clinicians, managers, commissioners, researchers etc. It continues to identify the need for an ECR, identifying many benefits for a paperless NHS. As the development of national ECR has been unsuccessful responsibility for the development of electronic patient records has been devolved down to individual NHS Trusts (Public Accounts Committee, 2011). Whilst the national strategies have not detailed the benefits of CCDSSs specifically they can easily be incorporated into electronic patient record. Many areas within the NHS for example Primary Care already have sophisticated systems for sorting patient level data and use systems to ensure that chronic disease are appropriately monitored (Souza et al., 2011). The section within this chapter will set the scene regarding the use of CCDSSs in general in healthcare. The detailed literature review in chapter 3 will look specifically at the role of CCDSSs in emergency care.

## 2.10 Computerised clinical decision support systems

CCDSSs use interactive computer software to support clinical decision-making (Friedman & Wyatt, 2010). They use various means to suggest a certain course of action to the clinician: alerts, reminders or on-screen prompts (Shiffman, 1999; Wyatt, J. C., 2001; Bryan & Boren, 2008). Depending on their use and application they can interpret tests, suggest diagnosis, make predictions, give advice, provide checklists, alerts and warnings, present evidenced-based recommendations or suggest a set of actions (Payne, 2000; Kaplan, 2001; Burt & Hing, 2005; Bryan & Boren, 2008). Figure 2.2 identifies the interactions between the patient, clinician, data systems and CCDSS. One of the earliest decision support systems was used for the diagnosis of acute abdominal pain (de Dombal, Leaper, Staniland, McCann, & Horrocks, 1972). Over the last 20 years there has been an explosion in the number of studies evaluating the role of CCDSSs. There is a growing consensus that CCDSSs have the potential to significantly improve healthcare (Kaplan, 2001). Several systematic reviews have identified the benefits of CCDSS with regard to patient safety, improve clinical performance and improved patient outcomes (Hunt, D., Haynes, Hanna, & Smith, 1998; Bates & Gawande, 2003).

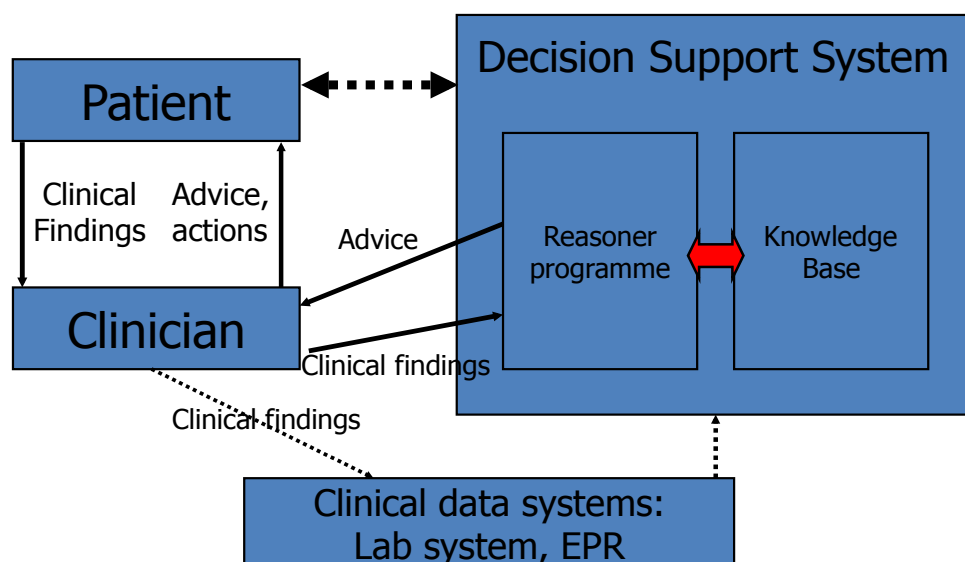


Figure 2.2 Anatomy of a CCDSS adapted from Friedman and Wyatt (2010)

A recent set of comprehensive systematic reviews have assessed the role of CCDSSs in improving the process of care and patient outcomes in six areas: primary prevention, diagnostic test ordering, drug prescribing, therapeutic drug monitoring, acute care and chronic disease management (Hemens et al., 2011; Nieuwlaat et al., 2011; Roshanov, P. et al., 2011a; Roshanov, P. et al., 2011b; Sahota et al., 2011; Souza et al., 2011). The six reviews have drawn the broad conclusion that the process of care can be improved with CCDSSs, although, in the case of drug prescribing the evidence was poor and the researchers could not recommend the use of CCDSSs (Hemens et al., 2011). In all six areas reviewed the number of studies that evaluated patient outcomes was relatively small and judged by the reviewers to be only of moderate quality. The only area where the weight of the evidence appears to be slightly stronger is in chronic disease management, where some studies did demonstrate an improvement in patients' health (Roshanov, P. et al., 2011a). These reviews examined randomized controlled trials (RCTs) and each underwent rigorous critical appraisal. The evidence from these reviews suggests a more cautious approach to the wholesale introduction of CCDSSs.

As well as the specific drivers for the introduction of CDSS in ED practice detailed in this chapter there are also broader influences relevant to all disciplines. These broad influences can be divided into the following four areas. (Wyatt, J. C., 2001; Grimshaw, J. et al., 2004; Grimshaw, J. & Eccles, M., 2004; Dijkstra et al., 2006; Friedman & Wyatt, 2010; Grimshaw, J., Eccles, Lavis, Hill, & Squires, 2012).

- 1) The explosion of information in healthcare
- 2) The increased complexity of healthcare interventions
- 3) The delay of implementing new evidence into routine clinical practice
- 4) The failure of more traditional methods of guideline dissemination

These factors are challenging researchers and clinicians alike and pose a series of questions.

- How do clinicians keep up-to-date with the overwhelming amount of new research published each week?
- How do clinicians interpret this evidence and then apply it to a specific patient situation?
- How can governments, healthcare organisations, academic institutions, hospitals, wards and departments disseminate new evidence in a timely way?
- What methods of dissemination ensure that patients are managed in an appropriate evidence-based way, regardless of the experience, expertise or up-to-date knowledge of the clinician?

One means of addressing all these issues is by the introduction and use of CCDSS. In this next section the role that CCDSS have with regard to patient safety will be considered.

#### *2.10.1 Computerised clinical decision support systems and patient safety*

The current climate within emergency care settings provides significant safety challenges. The workforce is less experienced and there are numerous vacancies at consultant level (Armstrong, White , & Thakore, 2008; Hassan et al., 2013). The pressure within the emergency care system is further compounded by rising patient attendances and the global economic crisis is preventing any increase in health care spending (Kings Fund, 2013; NHS Institute for Innovation and Improvement, n.d.). The clinical work in EDs is often complex and the environment more challenging than other more traditional settings (Heartfield, 2000). Distinctive features of decision-making in ED is the frequency and complexity with limited time and information (International Federation for Emergency Medicine, 2012). This creates a clinical environment with additional risk of adverse events and clinical incidents (Wears, Woloshynowych, Brown , & Vincent, 2010). The unique safety risks in ED is comprehensively detailed by Wears et al (2003):



- 1) ED overcrowding is commonplace
- 2) Emergency clinicians typically treat a wide variety of patients simultaneously
- 3) Time constraints are significant in UK EDs following the introduction of the hour performance standard
- 4) Some clinical conditions require time critical treatment and therefore clinicians have less time to assess and investigate
- 5) Emergency clinicians do not receive any automatic feedback about their clinician decisions from the admitting inpatient specialties. There is little opportunity to learn by this means
- 6) The riskiest procedures are uncommon and there is no opportunity for the development of these skills in non-critical situations.

Graber, Gordon & Franklin (2002) describe three types of diagnostic error: no-fault errors, system errors and cognitive errors. No-fault errors are those that are atypical, masked or as the result of illness. System errors are concerned with errors as a result of organisational or technical failures. Cognitive errors result from inadequate knowledge, faulty data gathering, inaccurate clinical reasoning or faulty verification. It is this third type of error that the majority of CCDSSs can have an impact on. There is evidence within the literature that CCDSSs can contribute to improvements in quality and/or safety (Bates & Gawande, 2003; Graham, T. et al., 2008; Scott, 2009; Black et al., 2011; Handel, Wears, Nathanson, & Pines, 2011). It is with all the current challenges in mind and the potential of CCDSSs to offset some of them that forms the basis for the research within this thesis. The final area to be addressed within this chapter is triage. The origins and current use of triage in EDs is analysed along with more general decision-making literature and the chapter concludes with a description of eTriage presented via screenshots.

## **2.11 Introduction to emergency department triage**

This section briefly describes the origins of triage and analyses its use in contemporary emergency health care. The use of the MTS (Mackway-Jones et al., 2006) is examined as it is a significant element within the CCDSS under investigation.

### *2.11.1 Emergency triage – historical development*

Triage, from the French verb *trier* “to sort” has its health care origins in the early 1800s when it was first used in the Napoleonic Wars (Rund & Rausch, 1981; Robertson-Steel, 2006). In this context soldiers with the least injuries, who could be treated relatively quickly and returned to the front line to fight, received priority for medical treatment. The reverse of this process is used in healthcare system across the developed world today as those with the most urgent need receive the highest clinical priority (Woolwich, 2000). The primary role of triage in contemporary EDs is to rapidly identify those newly arrived patients who are in immediate need of life saving intervention (Mackway-Jones et al., 2006). The care of these patients is prioritised over the care and treatment of all others and they are seen immediately. In doing so emergency triage plays a pivotal role in managing clinical safety and allocating nursing, medical and departmental resources appropriately. Triage systems are required when the demand for health care services outstrips the available resource. If there were enough clinical staff to assess and treat every patient as they arrived, there would be no need for a triage system.

The primary and over-riding function of triage is to identify patients with signs of critical illness or injury and ensure they receive immediate intervention which for some will undoubtedly be lifesaving. In doing so the triage process allocates the clinical priority of the patient and directs them to a clinical area where the patients’ needs are best met e.g. resuscitation. This process identifies the physical and staffing resources required to meet those needs (Mackway-Jones et al., 2006). For example if a patient was identified as having an abnormal pulse rate at triage they would be directed to a clinical area with monitoring facilities that

allowed close observation. As ED triage is the primary assessment that each patient receives and it dictates/directs the subsequent care the patient requires the importance of an accurate and appropriate assessment cannot be over-emphasised. The next section will examine the international development of contemporary triage systems.

#### *2.11.2 UK triage in the 1990s*

Triage systems were formally developed in the UK in the early 1990s following publication of The Patient's Charter (DH, 1991) a policy document from the then Conservative government. Standard 5 within the Charter stated that when patients arrived in an Emergency Department their need for treatment would be assessed by a registered nurse (DH, 1991). For the first time Emergency Departments had to provide a triage service; whilst some departments undertook triage when staffing levels allowed, all departments would now have to provide a consistent assessment process for every new patient (Woolwich, 2000). For the next decade departments developed their own triage systems and processes. There were huge variations in triage approaches not only in the UK but also in Europe, Canada, Australia and the United States (US) (Mackway-Jones et al., 2006; FitzGerald, Jelinek, Scott, & Gerdtz, 2010). Other triage systems developed in parallel during that time, the most notable being NHS Direct which provided telephone triage to advise the public how to deal with health problems and where to attend for urgent treatment (NHS Direct, n.d.). In General Practice telephone triage systems managed the demand for same day appointments. The patient was re-contacted by phone and their problem "triaged" only then was an appointment made if it was required (Gallagher, Huddart, & Henderson, 1998).

#### *2.11.3 International triage systems*

FitzGerald (1990) describes triage as "clinical justice" for the patient; a tool to organise the ED when there is a disparity between resources required and those that are available. As there is no control over patient attendances there will almost always be waiting times in emergency care. Triage ensures that those who are deemed safe to wait will not be clinically compromised due to a delay in

assessment/treatment. Although actual patient numbers per day/hour are fairly predictable, individual patient presentations are not, hence the need for triage. Over the last 20 years triage systems in several countries have been standardised to improve consistency in their application; MTS developed in the UK and adopted in other European Countries, the Canadian Triage and Acuity Scale (CTAS) and the Australasian Triage Scale (ATS) (FitzGerald et al., 2010).

Because of problems with overcrowding there have been calls to abandon triage in several countries, “streaming” being lauded as a better tool. Streaming identifies the clinical areas within an ED in which the patient would be best managed – minors, majors or resuscitation – and directs them to that area which has separate staffing. The Department of Health identified the streaming of patients as a method by which flow should be managed and in particular “see and treat” where patients in the minors stream were seen on arrival, treated and discharged. (DH, 2001).

In 2010 the Department of Health introduced Clinical Quality Indicators as a means of measuring clinical care and which still incorporated a time performance measure (DH, 2010a) . Interestingly the “triage” of patients was not included as a quality indicator. There was a resurgence of earlier discussions regarding the utility of triage (Windle & Mackway-Jones, 2003; Hughes, 2006). However, despite the lively professional debate about the real usefulness of triage, it remains a pragmatic solution to surges in demand. It is very unlikely that any ED in the UK or elsewhere in the world will ever have enough medical, nursing and physical resources to always meet demand. The MTS is the dominant triage system in UK EDs will now be explained in detail.

## **2.12 The Manchester Triage System**

In 1996 a collaboration between the RCN and the British Association of Accident and Emergency Medicine developed the first national triage scale, see Table 2.4 (Crouch & Marrow, 1996). In the same year the MTS was published, providing the first national triage system in the UK and incorporating the national triage scale (Mackway-Jones et al., 2006). Developed by a group of senior nurses and

emergency physicians from Manchester, England, the primary aim was to develop a robust triage system that was both valid and reliable and where variations in triage practice were minimised (Mackway-Jones et al., 2006).

**Table 2.4 National triage scale** (Mackway-Jones et al., 2006)

<b>Category</b>	<b>Associated colour</b>	<b>Time to see clinician in minutes</b>
Immediate	Red	0
Very urgent	Orange	10
Urgent	Yellow	60
Standard	Green	120
Non-urgent	Blue	240

### *2.12.1 The triage process using MTS*

The MTS is an algorithm based triage system, which requires the triage nurse to undertake the following three steps in order to identify the clinical priority for a patient:

1. Problem identification
2. Information gathering and analysis
3. Identification of the most significant clinical feature

### *2.12.2 Problem identification using MTS*

In order to establish the patient's main presenting problem the triage nurse takes a brief history from the patient/parent. History taking during triage is a complex process as it requires the nurse to illicit information from a patient not previously known and who has an undifferentiated and as yet undiagnosed problem (Edwards, 2007). Knowledge, skill and expertise are required to take a focussed history in the briefest of time and ensure that the root of the patient's problem is identified (Andersson, Omberg , & Svedlund, 2006). Once the main presenting problem has been established the triage nurse selects the appropriate presentational flow chart from a selection of 50, see Table 2.5.

Table 2.5 MTS presentational flowcharts (Mackway-Jones et al., 2006)

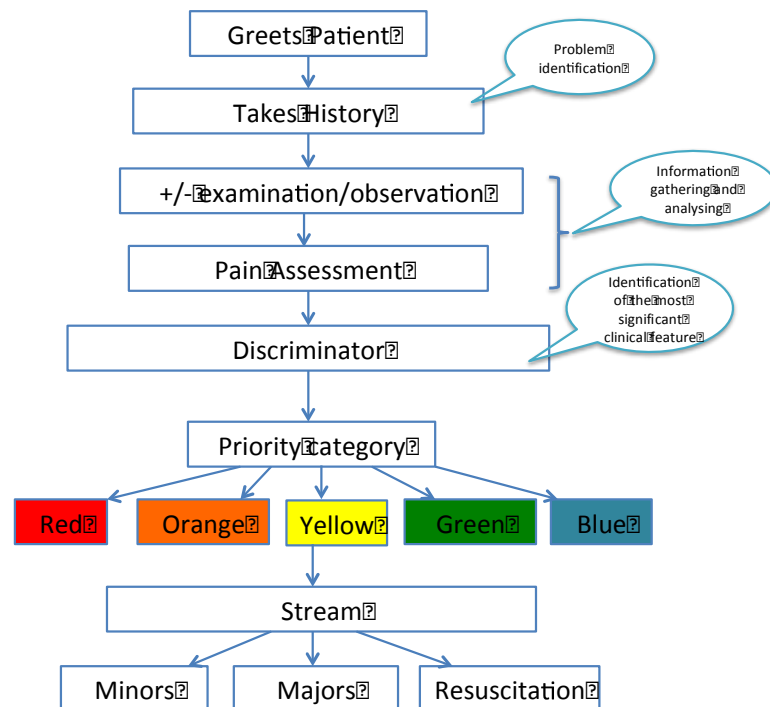
Abdominal pain in adults	Headache
Abdominal pain in children	Head Injury
Abscesses and local infections	Irritable child
Allergy	Limb problems
Apparently drunk	Limping child
Assault	Major Trauma
Asthma	Mental Illness
Back pain	Neck pain
Behaving strangely	Overdose and poisoning
Bites and stings	Palpitations
Burns and scalds	Pregnancy
Chest pain	PV bleeding
Collapsed adult	Rashes
Crying baby	Self Harm
Dental problems	Sexually acquired infection
Diabetes	Shortness of breath in adults
Diarrhoea and vomiting	Shortness of breath in children
Ear problems	Sore throat
Exposure to chemicals	Testicular pain
Eye problems	Torso injury
Facial problems	Unwell adult
Falls	Unwell child
Fits	Urinary problems
Foreign body	Worried parent
GI bleeding	Wounds

### *2.12.3 Information gathering and analysis*

Each presentational flow chart is unique but there are common features that require assessment in each flow chart e.g. airway, breathing or circulation problems. The flow charts/algorithms are based on a reductive methodology i.e. life threatening features are presented first and have to be eliminated before progression down the flow chart (Mackway-Jones et al., 2006). For an example of the chest pain and limb problems flow charts see Appendices 1 & 2. Once the presentational flowchart has been selected the triage nurse uses it to structure patient assessment and the gathering of further information. For example the recording of oxygen saturations and peak expiratory flow rate are required when using the asthma flow chart. Each flow chart uses discriminators to depict a specific clinical problem, sign or symptom. There are 197 discriminators in total; some are used repeatedly throughout the flowcharts e.g. severe pain, while others may only appear once e.g. presenting foetal part is only on the pregnancy flowchart. All the discriminators have a specific definition which is presented on the opposite page to the flowchart and at the back of the book in a discriminatory dictionary (Mackway-Jones et al., 2006). Each discriminator has an associated priority e.g. severe pain will always generate a “very urgent” priority.

### *2.12.4 Identification of the most significant feature*

Once the information gathering process is complete the triage nurse analyses all the additional information he/she has collected. The first discriminator, which highlights the most significant clinical feature of the patient’s presenting problem, is selected (working from the top of the flowchart downwards). Discriminators are grouped together at priority levels, which correspond with the National Triage Scale (see Table 2.4). Once the discriminator is selected the clinical priority – immediate, very urgent, urgent, standard, non-urgent – is automatically assigned. See Figure 2.3 for a diagrammatic representation of the triage process using MTS.



**Figure 2.3 The triage process using MTS**

From the description of this process it is easy to appreciate that novice triage nurses, after one day of theoretical training would require a significant period of direct supervision in order to develop competence. Repeated consultation of the MTS book is time consuming and in practice infrequently done, however trying to remember every chart, each discriminator and the associated priority is a significant challenge. To date there is no research which has investigated how nurses remember, use and apply MTS in clinical practice. See Appendix 3 for the documentation used prior to the introduction of eTriage

#### 2.12.5 MTS training

The widespread adoption of the MTS in the UK and other European countries is supported by standardised triage training using a “train the trainer” approach. To use the MTS departments must attend training which then gives them the accreditation to use the system (Advanced Life Support Group, n.d.). Once a department has trained key staff as MTS trainers the rest of the staff are then trained. MTS has been produced in a book format with chapters covering



decision-making, the triage method, pain assessment, patient management, audit, telephone triage and streaming (Mackway-Jones et al., 2006).

#### 2.12.6 Audit of MTS

Most face-to-face triage episodes in the UK, regardless of their setting i.e. ED, minor injury unit or walk-in centre rely on the clinical ability of the triage nurse to accurately assess the patient. One of the principle reasons for developing the MTS was to create a triage method that was consistent among users, valid and reproducible. Once developed and introduced into departments regular audit and feedback of results should take place. Individual triage nurses and departments as a whole would be able to judge the accuracy of their decisions and make improvements where required (Mackway-Jones et al., 2006). A process for auditing MTS is described in detail and involves the auditor (an experienced triage nurse) making retrospective judgements from the patient's clinical record about the following

- Completeness of the record
- Correct use of the presentational flow chart
- Pain score recorded
- Correct priority assigned *Mackway-Jones et al., (2006) p36*

From this explanation of the triage audit process one has to assume that, providing there is enough clinical documentation within the triage record that an experienced triage nurse can review the documentation and judge the quality and accuracy of the triage episode. However, there are some challenges to this approach within the literature, most controversially from Fitzgerald et al., (2010) who state

*“the diversity and complexity of health is such that it is never possible to have a correct answer for the triage of any individual patient. Indeed, there is probably no such thing as a “correct” answer, so there is no gold standard against which to measure accuracy”* *Fitzgerald et al., (2010) p4*

This position creates several problems for EDs and the safety of patients seen and assessed within them. If the nature of triage assessment has so many subjective variables as to render it both invalid and unreliable one has to question all the time and resources dedicated to the development and implementation of MTS, ATS and CTAS in hundreds of departments worldwide. Triage is a clinical risk management strategy, without which EDs could not function safely. Undoubtedly there has to be a dependable system that reliably identifies those that are critically ill or injured on arrival. Various studies have demonstrated that the MTS is a valid tool for: children, patients with chest pain, patients with pulmonary embolism and the critically ill (Cooke, M. W. & Jinks, 1999; Roukema et al., 2006; Providência et al., 2011; Paiva et al., 2012). MTS differs from CTAS and ATS as neither of these are algorithmic; both list physiological parameters and several other prompts/red flags to allocate priority. CTAS and ATS rely heavily on the triage nurses judgement, ultimately to make the decision regarding how long the patient can safely wait (FitzGerald et al., 2010). The more that individual judgement is required, the more likely that there will be variation between clinicians. In this respect MTS has a great strength as its prescriptive in nature, when applied correctly it will ensure that appropriate clinical priority is allocated regardless of the experience of the triage nurse (van der Wulp, van Baar , & Schrijvers, 2008).

#### *2.12.7 Inter-rater reliability of MTS*

To challenge the position of Fitzgerald et al., (2010) various studies have compared the inter-rater reliability of MTS. These studies demonstrate kappa scores which range between 0.4- 0.8 indicating that there is fair to substantial agreement when triage nurses are asked to assign a clinical priority to the same simulated cases (van der Wulp et al., 2008; Grouse, Bishop , & Bannon, 2009; Olofsson, Gellerstedt , & Carlstrom, 2009; Storm-Versloot, Ubbink, Chin a Choi , & Luitse, 2009). Three of these studies identified the correct answer, the gold standard through the consensus discussion of clinicians deemed as “experts” in MTS methodology (van der Wulp et al., 2008; Olofsson et al., 2009; Storm-Versloot et al., 2009). A recent systematic review assessing the inter-rater

reliability of MTS also identified a incidence of good and very good agreement (Parenti, Reggiani, Iannone , & Dowding, 2014). The challenge of this type of research and indeed local audit of triage decisions is that the reviewer lacks the visual cues that can play a significant role in clinical decision-making (Sbaih, 1998; Edwards, 2007). However, without the ability to digitally-record triage interactions as a means of judging accuracy and reliability, retrospective case note review remains the only practical and cost-effective option.

#### *2.12.8 Emergency triage – additional functions*

Over more recent years triage in ED's does more than prioritise clinical urgency and allocate an area within the department for the patients subsequent care. Triage nurses play a crucial role in improving quality and reducing the overall journey time for patients by additional interventions at triage such as: pain assessment and management, assessment of musculoskeletal injuries and referral for x-ray, initiation of management on a clinical pathway or direct referral to another service e.g. early pregnancy unit (Lindley-Jones & Finlayson, 2000; Boyd & Stuart, 2005). Adding additional functions to the triage role will lengthen the triage episode for some patients but these additional interventions can be of considerable benefit as they improve quality and/or safety and may reduce journey time as well. Table 2.6 summarises the additional functions at triage and their major contribution to clinical care

Table 2.6 Additional triage functions

<b>Triage functions</b>	<b>Quality</b>	<b>Safety</b>	<b>Reduction in journey time</b>
Immediate identification of critical illness/injury		✓	
Allocation of clinical priority		✓	
Assessment of early warning score (EWS)		✓	
Streaming (allocation of area in ED for subsequent care e.g. minors, majors, resuscitation)	✓	✓	✓
Provision of 1 <sup>st</sup> Aid	✓	✓	
Infection control (immediate isolation of potentially infectious patients)		✓	

Pain assessment and management	✓		
Assessment and referral for x-ray if appropriate	✓		✓
Initiation of diagnostic tests e.g. visual acuity, pathology investigations, urinalysis	✓	✓	✓
Commencement on a clinical pathway e.g. fast-track pathway for potential fractured neck of femur	✓	✓	✓
Direct referral to speciality e.g. mental health, early pregnancy unit	✓	✓	✓
Redirection to another health care facility e.g. dentist, podiatry	✓		✓

The role of the ED triage nurse is unique. There is no other sphere of nursing where rapid decision-making is the process upon which previously “unknown” patients are subsequently managed (Edwards, 2003). From newborn to frail older people, ED patients present with a myriad of undiagnosed and undifferentiated conditions. The triage nurse has to rapidly assess the severity of their presenting problem, usually with little previous knowledge of the patient and then decide on the urgency with which they need to be assessed by a clinician (Edwards, 2003). There are significant challenges in busy EDs to ensure consistent safe decision-making even when there is a triage system in place to guide the triage nurse. The rationale for the development of eTriage that underpins this study was two-fold: to improve the triage process (accuracy of decision-making, assessment and management of pain) and to provide a direct link to the clinical guidelines/pathways that may be relevant to the patient’s presentation. Before eTriage is presented for the reader in the final section a review of clinical-decision making theories and their application to triage practice is considered.

### **2.13 Clinical decision-making**

Clinical decision-making is the most frequently used term to describe decisions made by clinicians which relate to selecting a particular course of action, diagnosis or plan of care over another (Thompson, 1999). It is a distinct process whereby clinical knowledge, patient information, nursing knowledge and experience interact (Thompson & Dowding, 2001; Banning, 2008).

### 2.13.1 Theories of clinical decision-making

There are two main theoretical positions with regard to clinical decision-making in nursing and medicine, one analytical (Elstein, Shulman , & Sprafka, 1978) the other intuitive (Benner & Tanner, 1987). One of the most influential analytical clinical decision-making theories is the information processing model (Newell & Simon, 1972). From this the more commonly known hypothetico-deductive model was derived, initially in medical decision making (Elstein et al., 1978) and subsequently applied to nursing (Carnevali, Mitchell, Woods , & Tanner, 1984; Tanner, Padrick, Westfall , & Putzer, 1987). Four stages of medical decision-making were identified by Elstein et al., (1978) and are:

1. Cue acquisition
2. Hypothesis generation
3. Cue interpretation
4. Hypothesis evaluation

A key feature of models based on the information processing theory is that they are limited to some extent by a person's capacity to store and remember information (Newell & Simon, 1972). The mental processing that is required relies on triggers/cues that unlock knowledge from a persons long term memory (Thompson & Dowding, 2001).

Benner (1984) is often credited with offering an opposing theory regarding decision-making in nursing. In her research on the role of expertise in clinical nursing she identified that expert nurses used intuition. They no longer relied on critical analysis to make a clinical decision and were often not able to describe how they arrived at one particular decision over another (Benner & Tanner, 1987). Intuition was defined as

*“understanding without a rationale”* Benner & Tanner (1987) p 23

Intuition is what separates the expert from the learner and is not a conscious process (Banning, 2008).

More recently the concept of a cognitive continuum has been suggested as providing an alternative theoretical framework for clinical decision-making (Standing, 2008). It offers an alternative to the one-dimensional analytical or intuitive models and suggests that decisions are made along a continuum, with analysis at one end and intuition at the other (Thompson, 1999; Banning, 2008; Standing, 2008). It is the structure of the decision-making task, the number of cues and the availability of time that determines the approach used (Thompson & Dowding, 2001; Standing, 2008). Standing (2008) has revised the original cognitive continuum by Hamm (1988) and suggests that if task structure is low e.g. direct patient care and the time available is limited then decision-making is rooted in: intuition, reflective judgement, peer and patient aided judgement and system aided judgement (Standing, 2008; Noon, 2014). In reviewing clinical decision-making theories their applicability to triage practice can be considered.

### *2.13.2 Decision-making within the context of triage*

The clinical decision-making process during a triage encounter is the method by which the nurse arrives at the clinical priority for the patient. Identifying the correct clinical priority for the patient is the primary objective of triage. As time is limited and cues may be minimal, these features suggest a more intuitive approach (Standing, 2008) The use of triage tools (MTS, ATS, CTAS) provides an example of system-aided decision making (Smith, A, 2013a). They provide a significant function in guiding and supporting decisions when the pre-requisites for analytical decision-making, time and structure, are absent. The impact of CCDSS on decision-making processes within the emergency care setting are poorly understood (Hine, Farion, Michalowski , & Wilk, 2009). It is important to note that this research does not seek to explain any influences on decision-making per se but to highlight if a triage CCDSS alters the accuracy of triage decisions. The final section within this chapter describes eTriage and illustrates how a triage assessment takes place via the use of screenshots from the CCDSS.


## **2.14 eTriage**

eTriage was developed by clinical and IT staff within the hospital and upon which this research was conducted. Initial discussions began in 2008 about the possibility of a system and what functionality it might have. A specification was agreed and it was incorporated into the hospital's IT infrastructure plan for 2009. The researcher led the development of eTriage ensuring all the clinical and operational needs of the users within ED were met. CCDSSs developed with the users are strongly associated with high levels of user acceptance (Garg et al., 2005). eTriage is a module that is fully integrated within the hospital's Clinical Document Management System (CDMS). It inherited its user and document security, web housing and interface functionality from the CDMS. When the eTriage patient episode is complete the record is written to the existing document store in the CDMS. This ensures that the eTriage record is immediately available to all authorised users. eTriage was developed in Asp.net with AJAX and JavaScript extensions, storing data in a clustered SQL Server 2008 database. The completed system comprised of approximately 22000 lines of code in 91 files. During its three years of operation from 12/04/2010 to 17/06/2013 the system handled the ED attendances of 293,206 patients (Mansfield personal correspondence 2014). The following screen shots will guide the reader through the main areas of eTriage and follow the assessment of hypothetical patients, David with a limb injury and Jayne with potential neutropenic sepsis.

Once the patient has been registered on the hospital's patient administration system the data is pulled through into the initial "Patients Waiting" screen every 45 seconds (Figure 2.4). This screen is visible from any computer in the ED. Within the main body of this screen is information on:

- Arrival time
- Time waiting for the triage assessment, this turns red after 15 minutes
- Name, age and presenting complaint as describe to the ED receptionist
- Mode of arrival

Current Patient: None

 Emergency Department - Patients Waiting

**All patients awaiting triage**

Attended :	Waiting (mins):	Name :	Age :	Complaint :	Arrived By :
17:19	45	WILLIAM WOODLEY	34	LACERATION HEAD	Car
17:20	44	LEONARD LINDLEY	17	COLLAPSE	Ambulance
17:21	43	FRANK FRANK LINDLEY	53	UNWELL	Ambulance
17:24	40	LEONARD LINDLEY	16	PAIN UPPER LIMB	Car
17:30	34	WILLIAM WOODLEY	92	UNWELL	Car
17:38	26	LEONARD LINDLEY	29	INJURY FOOT	Car
17:40	24	LEONARD LINDLEY	48	REQUEST PSYCHIATRIC HELP	Ambulance
17:44	20	WILLIAM WOODLEY	9	INJURY UPPER LIMB	Car
17:47	17	LEONARD LINDLEY	53	PAIN ABDO	Car
17:48	16	LEONARD LINDLEY	73	UNWELL	Ambulance
17:50	14	LEONARD LINDLEY	65	FALL	Ambulance
18:03	1	LEONARD LINDLEY	3 months	FALL	Car

Demonstration/testing system only:

**Options**

- Chest Pain Only
- Children Only
- Ambulance Arrivals
- Non-Ambulance Arrivals
- Normal View (Complete Queue)

**Refresh**

Last updated: 21 seconds ago

[Click Here To Refresh Now](#)

**Status**

**ALERT!**  
One or more systems are reporting connection problems. Click here for more details.

PAS CONNECTION: OK

The options menu enables the users to filter the view to so that only the following appear

- Chest pain
- Children
- Ambulance arrivals
- Non-ambulance arrivals

All patients <16 years of age are highlighted in pink, patients who present with chest pain are highlighted in orange.

Figure 2.4 The triage queue



**Patient Details - DAVID**

Go back to the Triage queue

A & E No. :		Date/Time of Arrival :	
NHS No. :		Mode of Arrival : Ambulance	
Name : Address :			
Postcode :		Telephone :	
DOB / Age : 65		Religion : CE	
Occ / School :		Sex : M	
Type Of Incident : F			
Initiator of Attendance : O			
Next Of Kin / Person To Contact :		Presenting Complaint : FALL	
Relationship :		Where :	
Address :		What :	
Telephone :		Why :	
GP Details :			
Telephone :			

**Patient Notes**

Hearing Impaired: ☐    Visually Impaired: ☐  
 Mobility Impaired: ☐  
 Other Special Needs :   
☐ Courtesy Call   ☐ Standby   ☒ Neither

Previous A&E Attendances : 2  
 Attendances in Last 14 Days : 0  
 Last Attendance : 14/12/2004

**Logged In Status**

**Not Logged In**  
 User Name :   
 Password :

**Triage**

Bypassing Triage will generate a part-complete document for this patient.

Rapid Assessment and Treatment service.

☐ Senior Review    ☐ Freq. Patient

**Called No Response**

Once a patient has been selected (by clicking on them) all their demographic information appears on the main body of the screen.

On the top right hand side of the screen the triage nurse can enter information if the patient has a disability, if their arrival was pre-altered by the ambulance service (Courtesy call or Standby).

There is also accessible information from this screen on previous attendances

Figure 2.5 Patient demographic screen

Once the triage nurse has logged on the triage process can begin

 Patient Details - DAVID 

 Go back to the Triage queue

A & E No. :		Date/Time of Arrival :	
NHS No. :		Mode of Arrival :	Ambulance
Name :			
Address :			
Postcode :		Telephone :	
DOB / Age :	65	Religion :	CE
Occ / School :		Sex :	M
Type Of Incident :	F		
Initiator of Attendance :	O		
Next Of Kin / Person To Contact :		Presenting Complaint :	FALL
Relationship :		Where :	
Address :		What :	
Telephone :		Why :	
GP Details :			
Telephone :			

Patient Notes

Hearing Impaired: ☐

Visually Impaired: ☐

Mobility Impaired: ☐

Other Special Needs :

☐ Courtesy Call ☐ Standby ☒ Neither

Previous A&E Attendances : 2

Attendances in Last 14 Days : 0

Last Attendance : 14/12/2004

Logged In Status

Logged In: P BENNETT

Triage

Bypassing Triage will generate a part-complete document for this patient.  
  
Rapid Assessment and Treatment service.  
☐ Senior Review ☐ Freq. Patient


Called No Response


Figure 2.6 Logging on

The first step in the patient's assessment is to decide if they have sustained a minor injury (Figure 2.7). These two options for triage will take the user through an abbreviated triage process for patients with minor injuries, which has no free text options. Alternatively if the patient has not sustained a minor injury the triage process enables a brief history to be documented.

*This patient, David has sustained a minor injury and the "Yes – Choose Presentation" option is selected.*

Current Patient: DAVID [REDACTED]

 Triage - DAVID [REDACTED] Age:65 FALL

 **Minor Injury?**

Is this a minor injury suitable for direct streaming to minors?

**If there is no clear history of trauma - Triage as normal**


Figure 2.7 Minor triage or full triage

There now 15 presenting complaints to choose from, each represents one of the MTS presentational flowcharts that is applicable to patient who are injured (Figure 2.8)


*David has an ankle injury, therefore Limb Problems is selected*

Current Patient: DAVID [REDACTED]

---

 Triage - DAVID [REDACTED] Age:65 FALL

---

 **Minor Injury?**  
Is this a minor injury suitable for direct streaming to minors?

**If there is no clear history of trauma - Triage as normal**

Assault

Back pain

Bites and stings

Burns and scalds

Dental problems

Ear problems

Eye problems

Facial problems

Falls

Foreign body

Head injury

Limb Problems

Neck pain

Torso injury

Wounds

**Summary**

DAVID [REDACTED]

Figure 2.8 Minor triage

The MTS presentational flow chart Limb Problems is shown (Figure 2.9). Through a reductive approach the triage nurse works their way down the flowchart until the first relevant discriminator is identified. There is a “hover” function with the computer mouse to enable the triage nurse to review any discriminator definition, see recent problem example shown below. The discriminators are ordered in priority and with their associated priority colour (red, orange, yellow, green, and blue) (see Table 2.4)

*David’s ankle injury happened that morning on his way to work. There are no other discriminators relevant in a higher priority category – Recent problem is selected*

Current Patient: DAVID

Triage - DAVID Age:65 FALL

**Limb problems**  
See also: Limping child

**Immediate:**

Airway Compromise	Inadequate Breathing	Exsanguinating haemorrhage	Shock
-------------------	----------------------	----------------------------	-------

**Very Urgent:**

Severe pain	Acutely short of breath	Critical skin	Vascular compromise
Uncontrollable major haemorrhage			

**Urgent:**

Pleuritic pain	Gross Deformity	Open fracture	Uncontrollable minor haemorrhage
New neurological deficit	Bleeding disorder	Inappropriate history	Moderate pain

**Risk limit**

**Standard:**

Recent mild pain	Deformity	Swelling	Recent problem
------------------	-----------	----------	----------------

**Non-urgent:**

A problem arising in the last week is said to be recent

**Summary**

DAVID  
Limb problems

Abandon Triage

Figure 2.9 Limb problem flowchart

The next screen shows the options for pain assessment and management (Figure 2.10). As the patient has not been identified as having moderate or severe pain the options to give a score above 3 are not available. If for example David had been triaged on the previous screen as having a gross deformity (yellow priority) the options for moderate pain (scores 4-6) would be displayed.

*David's pain is mild and he scores it at a 3.*

The screenshot displays the 'Clinical Document System' interface for a patient named DAVID. The patient's details are: Triage - DAVID, Age: 65, FALL. A green box labeled 'Limb problems' is visible. The 'Pain Assessment' section shows a scale from 0 to 10, with 0, 1, and 2 highlighted in green. Below the scale, there are checkboxes for 'Unable to assess pain level' and 'Reason:'. The 'Analgesia' section includes checkboxes for 'Pyrexia', 'Paracetamol', 'Ibuprofen', 'Codeine', 'Further assessment for morphine', 'Other', 'Already Taken', and 'Declined analgesia'. The 'X-Ray' section has a checkbox for 'X-Ray'. A 'Continue' button is at the bottom right. A 'Summary' window is open on the right, showing 'DAVID', 'Limb problems', and 'Priority: Standard', with an 'Abandon Triage' button. A blue arrow points from the text on the right to the 'Summary' window.

By selecting a discriminator the clinical priority/triage category is automatically allocated by eTriage.

In this example the selection of the discriminator "recent problem" has allocated a standard (green) triage priority

Figure 2.10 Pain assessment and pain management

Current Patient: DAVID

**Triage - DAVID** Age:65 FALL

• If a pain score is recorded, at least one of the Analgesia options must be completed.

**Limb problems**

**Allergies:**

NKDA ☒

Allergic To:  If none known, please enter NONE

**Pain Assessment:**

0 1 2 3 4 5 6 7 8 9 10

Unable to assess pain level ☐ Reason:

**Analgesia:**

Paracetamol:  Mg

Ibuprofen:  Mg

Other:

☐ Already Taken:

☐ Declined analgesia

**X-Ray:**

X-Ray ☐

**Summary**

DAVID

Limb problems

Priority: Standard

Abandon Triage


Continue

If analgesia is not administered or if the options taken are not selected, the triage cannot progress.

Figure 2.11 Prompt to ensure analgesia is administered

Whilst not relevant to David's presentation this screen demonstrates the Early Warning Score function of eTriage (Figure 2.12). It would appear as a mandatory screen if appropriate to the presenting problem e.g. chest pain, abdominal pain.

Current Patient: DAVID

 Triage - DAVID Age:65 FALL

**Limb problems**

**Early Warning Score:** Assessed: ☐ Here ☐ Resus ☐ Majors ☐ Sub Wait ☐ Not Applicable

Partial set of observations can not be recorded here. Record in free text.

Observation	Value	EWS
Temperature	<input type="text"/>	
Blood Pressure	<input type="text"/> / <input type="text"/>	
Heart Rate	<input type="text"/>	
Respiratory Rate	<input type="text"/>	
SaO2 saturation (%)	<input type="text"/>	
GCS/AVPU	Please Select ...	
Urine Output	Please Select ...	
Total Early Warning Score :		0

**Summary**

DAVID  
Limb problems  
Recent problem  
Priority: Standard

Paracetamol 1000Mg  
Streaming: Minors

The stream in which David has been assigned is now allocated. This has happened automatically as David was triaged as a minor injury.

For patients who do not have a minor injury the option to select either the minors or majors stream is at the end of the eTriage process


Figure 2.12 Early warning scoring



The summary on the right hand side of the screen identifies the assessment so far and the analgesia David has been given (Figure 2.13). The triage nurse now has the option of selecting any of the departmental pathways or guidelines that are relevant to the patient's problem. The documentation that is available on this screen has been mapped to all the MTS flow charts so that only the ones relevant for that problem are displayed.

*For David's ankle injury the Ankle/Foot Inversion Injury Proforma would be selected.*

Current Patient: DAVID

 Triage - DAVID Age:65 FALL

**Limb problems**

**Documentation:**

- DVT ED pathway **Print?** ☐
- Ankle/Foot Inversion Injury Proforma** **Print?** ☐
- IGTN advice **Print?** ☐
- potential femoral neck fracture **Print?** ☐
- Previous ED attendances **Print?** ☐

**Summary**

DAVID  
Limb problems  
Recent problem  
Priority: Standard

Paracetamol 1000Mg  
Assess Early Warning Score in N/A  
Streaming: Minors

**Abandon Triage**

**Continue**

Figure 2.13 Option to select a clinical pathway/guideline

This is the final screen before the end of the triage episode (Figure 2.14). There are options to request bloods. There is also the option to document if at this stage the patient decided not to wait. Some patients might be seen and treated at triage e.g. a patient with a stubbed toes who only requires advice and simple strapping. This could be documented in this screen

*No further actions are required for David and the “Finish & Print” button is pressed. The eTriage record and any associated documentation is stored electronically in the CDMS and also printed in ED reception to form the beginning of the full ED clinical record.*

Current Patient: DAVID

Triage - DAVID Age:65 FALL

**Limb problems**

**Consultant Of The Day:**

• Consultant Of The Day not set. Please contact the ED secretaries to have this set up as soon as possible.

**Recommendations:**

**Bloods**

☐ ED General ☐ ED Orthopedic  
☐ ED Cardiac ☐ ED Sepsis  
☐ Trop T if patient > 12 hrs ☐ ED PV Bleed  
☐ ED Abdominal ☐ ED Other (Please Enter)

**Other recommendations**

EWS assessment at: N/A

**Triage See and Treat / Redirection**

**Summary**

DAVID  
Limb problems  
Recent problem  
Priority: Standard  
Paracetamol 1000Mg  
Assess Early Warning Score in N/A  
Streaming: Minors

Abandon Triage

**Decided not to wait**

☐ Patient decided not to wait

**Details:**

**Finish and Print**

Finish & Print

Figure 2.14 Final triage screen

There are several features built into eTriage to prompt the early focussed management of patients who present with possible neutropenic sepsis.

- 1) A patient on chemotherapy would initially be “flagged” in eTriage if they were on the hospitals cancer database. See Figure 2.15
- 2) There would be an eAlert in eTriage to prompt the triage nurse to consider if neutropenic sepsis could be a feature of the patient presentation. See Figure 2.15
- 3) If the triage nurse suspected a (non-cancer database) patient had symptoms of neutropenic sepsis they would select the neutropenic sepsis care pathway. See Figure 2.16. The neutropenic sepsis pathway would print at the end of the Triage episode. See Appendix 4
- 4) A final prompt would instruct the nurse to inform the shift leader immediately of the patient.

Current Patient: [REDACTED]

Triage - [REDACTED] Age:53 INJ TO HAND

Unwell adult  
See also: Collapsed adult

**Immediate:**

Airway Compromise Currently fitting	Inadequate Breathing	Shock	Hypoglycaemia
--	----------------------	-------	---------------

**Very Urgent:**

Severe pain Special risk of infection Cold	Altered conscious level Non-blanching rash	Signs of meningism Purpura	Acute neurological deficit Very hot adult
--	---	-------------------------------	--

**Risk limit**

**Urgent:**

Rapid onset Significant haematological history	History of recent foreign travel Widespread discharge or blistering	New neurological deficit Hot adult	Known immunosuppression Moderate pain
---	--	---------------------------------------	--

**Standard:**

Recent mild pain	Warmth	Recent problem
------------------	--------	----------------

**Non-urgent:**

**Summary**

Unwell adult

Abandon Triage

**This patient is on a cancer pathway**  
Could the patient be presenting with neutropenic sepsis?

Figure 2.15 Neutropenic sepsis management - eAlert

Unwell adult

Documentation:

Neutropenia checklist

Previous ED attendances

Print? ☐

Print? ☐

Continue

JAYNE

Unwell adult

Very hot adult

Priority: Very Urgent

Assess Early Warning Score in Resus

Referred :

Streaming: Resus

Abandon Triage

Figure 2.16 Neutropenic sepsis management

## **2.15 Summary**

This chapter has considered all the influences that underpinned the rationale for the development of a CDSS to support triage practice. The demand for emergency services has risen exponentially in the last decade. An inexperienced workforce often supplemented with locum doctors because of recruitment problems means that ensuring EDs achieve the mandated performance targets is seen by some as an impossible task. Healthcare professionals are striving to deliver high quality care in often unmanageable circumstances. The current issues that are facing emergency care services have never been so challenging. There are no “quick fixes” as economic restrictions continue and demands for health services continue to grow. Novel approaches are required to ensure the workforce can deliver high quality care. The development of eTriage was one such idea, conceived by the researcher as a means of addressing the quality and safety challenges in the clinical environment.

Emergency triage is a complex process unique to the speciality of emergency nursing. It requires rapid decision making to ensure patients are prioritised correctly and receive care and treatment promptly. Triage is essentially a risk management tool to ensure that waiting to see a clinician does not compromise a patient’s clinical condition. MTS is the most frequently used system in the UK and many European countries yet its accurate use can be challenging. Triage nurses are required to remember a significant number of criteria to use the system correctly. Long queues for triage assessment and the management of multiple clinical demands can make triage work stressful. The CCDSS eTriage was developed to improve the quality and safety of triage decisions and overall safety in the ED for example by providing a direct accessible link to relevant departmental clinical guidelines. It has many other functions, for example it ensures that clinical observations are always recorded when indicated. A literature review of the role of CCDSSs in acute care is presented in the next chapter.

## CHAPTER 3: LITERATURE REVIEW

### 3.1 Introduction

The objective of this focussed literature review is to expose all the current research that has evaluated the impact of CCDSS on the care of patients attending EDs. A comprehensive search strategy detailed below was developed to ensure relevant studies were identified. This is followed by an overview of the selected studies, which identifies where the studies were undertaken and what clinical conditions were subject to CCDSS. The functionality of the systems in use in departments is then highlighted to identify the methods used for decision-support. The literature review then critically appraises the methodological quality of the included studies by analysing the predominant methods used. The conclusion to this review synthesises what is known and not known from the identified body of literature about the effectiveness of CCDSSs in Emergency Care.

### 3.2 Search strategy

The search strategy involved searching the following journal databases, electronic resources and grey literature websites for literature published between 1994 and 2014. See Table 3.1. The initial literature search took place in 2010 and was updated in 2013, with a final refinement in February 2014.

Table 3.1 Search strategy of electronic resources

<u>Journal Databases</u>
Medline hosted by EBSCO
CINAHL hosted by EBSCO
EMBASE via NHS evidence
<u>Electronic Resources</u>
The Cochrane Collaboration <a href="http://www.cochrane.org">www.cochrane.org</a>
Centre for Reviews and Dissemination including database of abstract of reviews of effectiveness (DARE), NHS economic evaluation database and the Health Technology Assessment (HTA) Programme via <a href="http://www.crd.york.ac.uk">www.crd.york.ac.uk</a>
National Institute for Health Service Research <a href="http://www.nets.nihr.ac.uk">http://www.nets.nihr.ac.uk</a>

Implementation Science <http://www.implementationscience.com>

Grey Literature websites

Zetoc (database of conference proceedings) <http://zetoc.mimas.ac.uk>

EThOS (electronic theses online service) <http://ethos.bl.uk>

OpenGrey (European grey literature) <http://www.opengrey.eu/>

NHS Evidence Health Information Resources <https://www.evidence.nhs.uk/nhs-evidence-content/journals-and-databases>

The contents of the following health informatics journals were manually searched for research into the use of CCDSS in EDs:

- Journal of the American Medical Informatics Association
- International Journal of Medical Informatics
- Informatics for Health and Social Care
- BMC Medical Informatics and Decision Making
- Journal of Biomedical Informatics
- Health Informatics Journal

Search strategies for each journal database (Medline, CINAHL & EMBASE) were constructed (see Appendices 5, 6 & 7). Grey literature was identified via the websites listed in Table 3.1 and personal correspondence with researchers in the field. A total of 1822 journal articles, reports and reviews were identified through the whole literature searching process. The papers initially selected considered some aspect of decision support in ED. See Table 3.1. These were all preliminarily screened by title and abstract to identify CCDSS research in ED. This revealed 399 papers. A secondary review identified which were primary research studies. One hundred and eighty were then screened against further specific inclusion and

exclusion criteria (below). Twenty-three studies were finally selected for inclusion.

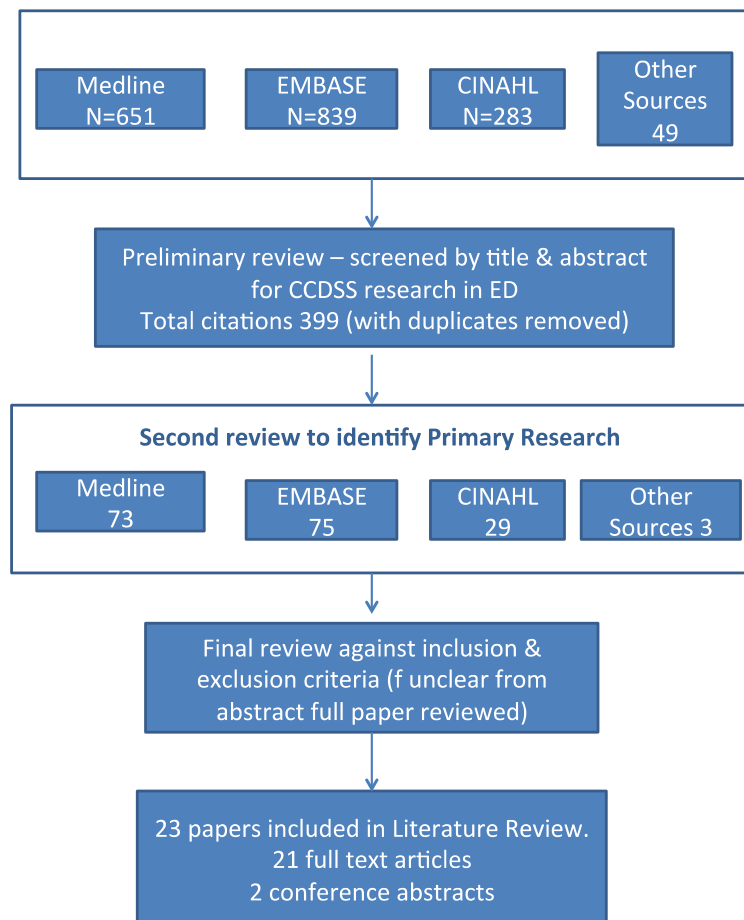


Figure 3.1 Database search results and screening process

### 3.3 Inclusion and exclusion criteria

The studies included in this literature review had to meet three principal inclusion criteria. Studies that had any of the characteristics listed in the exclusion criteria were rejected.

#### Inclusion

- The study had to take place in an emergency department
- The study had to report primary research on the use of a CCDSS for an acute problem in face-to-face situation.
- The study had to compare CCDSS with usual care.



## **Exclusion**

- Studies identifying only the views of system users
- ED tracking systems
- Technical development of CCDSS (bench testing/simulated settings)
- Bed management systems
- Paper based decision support tools
- Radiology imaging systems
- Pathology ordering systems
- Pharmacy systems for drug prescribing (dosing/error reduction)
- Systems used only by patients
- Health screening/surveillance

### *3.3.1 Justification of inclusion and exclusion criteria*

Studies that considered the use of CCDSSs for acute problems outside of the ED setting e.g. outpatient departments, primary care settings were excluded. The unique challenges of the ED clinical environment have created a driver for the development of CCDSSs for this particular setting (Georgiou et al., 2013). The ED setting has unique issues for system implementation and the use of appropriate methods to evaluate CCDSSs. Other clinical areas have different challenges not directly relevant to this research.

Studies that have evaluated CCDSSs use, for example, over the telephone or as a reminder system for health screening e.g. to administer flu vaccinations have also been excluded (Dexheimer et al., 2011). The use of reminder systems in EDs appear to be restricted to a problem peripheral to the patient's presenting clinical condition. The use of decision support via the telephone is increasingly significant but again is not directly relevant to this research. Finally, studies that investigated

the feasibility of a CCDSS or its technological development were not included as they were not measuring the direct benefit on patient care.

Computerised Physician/Provider Order Entry (CPOE) systems deserve a special note as they have been subject to extensive research in the US (Eslami, Abu-Hanna , & de Keizer, 2007; Georgiou, Williamson, Westbrook , & Ray, 2007; Niazkhani, Pirnejad, Berg , & Aarts, 2009; Reckmann, Westbrook, Koh, Lo , & Day, 2009; Main et al., 2010; Georgiou, Prgomet, Markewycz, Adams , & Westbrook, 2011) . CPOE systems allow the direct ordering of tests/investigations (pathology & radiology) and or the prescription of medications via a computer. There are a smaller but growing number of studies that have evaluated the benefits of CPOE on ED patients, workflow, safety and some have incorporated decision support (Georgiou et al., 2013). After careful consideration the majority of studies that assessed the effects of CPOE within an ED were excluded. Studies were excluded if they just evaluated drug dosing (Kirk, Li-Meng Goh, Packia, Min Kam , & Ong, 2005; Terrell et al., 2010; Griffey, Lo, Burdick, Keohane , & Bates, 2012) or the reduction of prescribing errors (Sard et al., 2008; Mohr, Faine, Harland, Porter , & Draus, 2013). Only the studies involving the use of CPOE that had a specific clinical decision support tool embedded into the system were included.

For practical reasons only English language research papers were included.

As CCDSSs are a relatively novel health care intervention with little research before the 1990s, studies were selected from the last 20 years (1994-2014). As the literature search progressed it became evident that there was only a small number of CCDSS studies that had taken place in EDs. In response, and in order to increase the understanding of how CCDSSs in EDs have been evaluated, a decision was taken to include all study designs (and to disregard issues of methodological quality at this stage). Identifying the strengths and weaknesses of designs and how they had been addressed would help inform the overall design of the study within this thesis.

Once the included studies were finalised a review of their reference lists was undertaken to identify any further research of relevance. The reminder of this

literature review critically appraises the primary research that has evaluated the impact of CCDSS in EDs.

### **3.4 Overview of included studies**

Twenty three studies were included in the review; Table 3.2 outlines their main characteristics. The next four sections provide a summary of the content of the Table 3.2. Twenty of the studies were undertaken in the last decade, highlighting that the use of CCDSSs in EDs is relatively new.

Table 3.2 Overview of the key characteristics of the studies included in the literature review

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Bond, Djogovic, Villa-Roel, Bullard, Meurer & Rowe (2013). Canada	To determine if electronic clinical practice guidelines (eCPG) improve the management of patient with <b>severe sepsis and septic shock</b> .	<b>Before and after study.</b> Pre and post eCPG outcomes were compared between 51 cases and 51 matched retrospective controls.	<ul style="list-style-type: none"> <li>• Time to lactate measurement</li> <li>• Time to blood culture collection</li> <li>• Time to antibiotic administration.</li> <li>• Delivery of fluid bolus</li> <li>• Administration of vasopressors for unresponsive hypotension</li> <li>• Measurement of central venous pressure (CVP)</li> </ul>	<p>There was a statistically significant difference in antibiotics within 3hrs (<math>p=0.034</math>) and use of vasopressors (<math>p=0.019</math>), measurement of CVP (<math>p&lt;0.0001</math>).</p> <p>Overall finding suggested that patients in the eCPG group were treated more aggressively.</p>
Britton, Bloch, Strout & Baumann (2013). United States	What is the effect of a CCDSS order set in a CPOE for <b>sexual assault victims</b> ?	<b>Before and after study.</b> Pre-test post-test study  Pre-test (n=322), post-test (n=131) design over 10 year period.	<ul style="list-style-type: none"> <li>• Compliance with the order set</li> </ul>	Pre-test compliance was 4.4%. post-test was 82.4% ( $p<0.001$ ).
Dexheimer, Abramo. Arnold, Johnson, Shy, Ye, Fan, Patel & Aronsky (2013). United States	Does the use of a CCDSS detect and then improve the care of <b>children with asthma</b> by prompting clinician to use a guideline.	<b>Prospective RCT.</b> Intervention n=358. Control n=346.	<ul style="list-style-type: none"> <li>• Time to disposition</li> <li>• Admission rate,</li> <li>• ED length of stay (LOS)</li> </ul>	There was no statistically significant difference between control and intervention groups for time to disposition, admission rate, ED LOS.

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Jones B, Jones J, Stoddard, Vines, Jephson, Ferrari, Post, Briggs, Griffin, Kumar, Allen, Haug & Dean (2013) United States	The impact of CCDSS on the management of patients presenting to ED with <b>community acquired pneumonia</b> .	<b>Before and after study.</b> A real time CCDSS was developed to assess pneumonia severity and make management recommendations. Pre (n=2349) and post (n=2583) implementation outcomes were compared in 4 EDs.	<ul style="list-style-type: none"> <li>• Over diagnosis</li> <li>• Hospital admission</li> <li>• Guideline-concordant triage</li> <li>• LOS</li> <li>• Inpatient mortality</li> </ul>	<p>Use of the CCDSS increased the number of appropriate hospitalisations (p=0.02) and a reduction in inpatient mortality (p=0.02).</p> <p>Outcomes were adjusted for disease severity.</p>
Gibbs, Baumann, Lyden, Strout & Knowles (2012). United States	Evaluating the impact of a CDSS on the core measures for the treatment of patients with <b>community acquired pneumonia</b> .	<b>Interrupted time series design.</b> Before (n=613) and After (n=572) CCDSS implementation.	<ul style="list-style-type: none"> <li>• Blood cultures prior to antibiotics</li> <li>• Antibiotics within 6hrs of arrival</li> <li>• Appropriate antibiotic selection</li> <li>• Mean time to antibiotic administration</li> </ul>	There was a statistically significant difference in: blood cultures prior to antibiotics (p<0.001), antibiotics within 6hrs (p=0.004), appropriate antibiotic selection (p=0.0112).

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Lim, Bawden, Wing, Villa-Roel, Meurer, Bullard & Rowe (2012). Canada	Effect of an eCPG on adults presenting to ED with <b>febrile neutropenia</b> .	<b>Retrospective comparative cohort study.</b> 4 EDs. The intervention ED (was the ED designated ED for patients on cancer treatment and developed the eCPG, it was widely used there). The other 3 EDs were controls. eCPG not mandatory.  n=201 in study. 128 in intervention ED. 73 in the 3 control EDs.	<ul style="list-style-type: none"> <li>• Use of eCPG.</li> <li>• Time intervals from triage to antibiotic.</li> <li>• LOS in ED,</li> <li>• Investigations</li> <li>• Treatment</li> </ul>	eCPG use was 37.8% overall. Intervention 57%, control ED1 19%, ED2 0%, ED3 0%. In intervention ED ECGs (p=0.03) and blood cultures (p=0.04) were performed more frequently. Reduction in triage to Dr assessment (p=0.001), and triage to 1 <sup>st</sup> antibiotic (p=0.02). There was no statistically significant difference in eCPG group from time to antibiotics although it was slightly lower. Knowledge of eCPG improved care for all patients.
Raja, Ip, Prevedello, Sodickson, Farkas, Zane, Hanson, Goldhaber, Gill & Khorasani (2012). United States	Effect of CPOE on the use and yield of computerised tomography pulmonary angiography (CPTA) for <b>pulmonary embolism</b> .	<b>Before and after intervention study</b> over 6 year period. Pre CCDSS n=3855. Post n=2983 had CPTA ordered.	Use and yield of CTPA.	Decrease in the use of CTPA with CCDSS from 26.4% to 21.2% (p=0.0379).  The % of positive CPTA increased with the CDSS from 5.8% to 9.8% (p=0.032).

Author and country	Aim of Study and Clinical condition	Study design and sample	Key outcome measures	Results
Carman, Phipps, Raley, Li & Thornlow (2011). United States	Evaluation of CCDSS embedded into Allscripts© to improve adherence to national guidelines for the management of <b>skin and soft tissue infections</b> .	<b>Before and after study.</b> Pre-test n=205. Post-test at 6 weeks n=383, at 12 weeks n=285.	<ul style="list-style-type: none"> <li>• Correct antibiotics</li> <li>• Wound culture</li> <li>• Chlorhexidine scrubs</li> </ul>	Adherence to antibiotics (p <0.001) and Chlorhexidine scrubs (p <0.001) Use of the CCDSS declined over the course of the study. Use of the CCDSS only had impact on Chlorhexidine. Although antibiotic adherence improved this did not correlate with use of the CCDSS.
Drescher, Chandrika, Weir, Weintraub, Berman, Lee, Burskirk, Wang, Adewunmi & Fine 2011). United States	Does the use of a CCDSS embedded in a CPOE improve the use and yield of CTPA in the diagnosis of <b>pulmonary embolism</b> ?	<b>Before and after intervention study.</b> Prospective intervention group with retrospective pre-intervention comparison group. Pre (n=205) and post (n=229) implementation.	Did the rate of positive CTPA increase with CCDSS?	Pre-intervention positive CTPA 8.3% (CI 95% 4.9%-12.9%). Post-intervention positive CTPA 12.7% (CI 95% 8.6%-17.7%). This is a 4.4% (95% CI -1.4%-10.1%) increase in the proportion of positive results. The proportion of DDimer tests decreased from 70% to 63%.

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Nelson, Smith, Jared & Younger (2011). United States	Does a CCDSS to alert the physician of <b>sepsis</b> and suggest specific actions to improve care?	<b>Before and after prospective study.</b> Phase 1 data collected but staff not alerted. Phase 2 staff alerted – sample size not evident in paper. No reply from email correspondence with author	Timeliness of: <ul style="list-style-type: none"> <li>• Blood cultures</li> <li>• Lactate,</li> <li>• Chest x-ray</li> <li>• Antibiotics</li> </ul>	The Dr often diagnosed sepsis before the CCDSS. With the CCDSS chest x-ray before admission (OR 3.2 95% CI 1.1-9.5) and collection of blood cultures were more frequent (OR 2.9 95% CI 1.1-7.7). Blood cultures were the only thing performed significantly faster (p=0.032). Frequency and timeliness of lactate sampling and provision of antibiotics remained unchanged.
Melnick, Genes, Chawla, Akerman, Baumlin & Jagoda (2010). United States	Does a CCDSS for <b>syncope</b> change Dr behaviour and improve guideline adherence?	<b>Before and after study.</b> A prospective study with retrospective controls. Pre n=410 and post n=301 intervention.	<ul style="list-style-type: none"> <li>• Admission rate</li> <li>• Number of CT scans ordered</li> </ul>	Statistically significant difference in admission rates (p=0.036). No difference in CT imaging (p=0.358).
Jadav, Lloyd, McLauchaln & Hayes (2009). United Kingdom	Evaluation of the effects of making <b>pain</b> scoring mandatory for children attending ED. Did it increase the provision of analgesia?	<b>Before and after study.</b> Retrospective case note review comparing audit results before and after the introduction of mandatory pain scoring. Pre-intervention n=187. Post-intervention n=163	<ul style="list-style-type: none"> <li>• Number of children pain scored</li> </ul>	There was an increase in the number of children who has their pain scored (p<0.001). No significant change in those given analgesia.



Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Kwok, Dinh, Dinh, Chu (2009). Australia	Assess the effects of a CDSS on improving adherence to <b>asthma</b> guidelines in adults.	<b>Before and after study.</b>  Observational pre and post intervention design comparing CCDSS with historical controls (n=50 study group n=50 control)	Quality of care judged by documentation of: <ul style="list-style-type: none"> <li>• Precipitating factors</li> <li>• Previous ICU history,</li> <li>• Smoking history</li> <li>• Peak flow results</li> <li>• Asthma severity</li> <li>• Discharge plan</li> <li>• Smoking cessation advice</li> <li>• Steroid on discharge</li> </ul>	Increased documentation of asthma severity (p<0.01) and discharge plan documentation (p<0.01) despite regression model adjustment for triage category and seniority of doctor.
Niemi, Geary, Quinn, Larrabee & Brown (2009). United States	CDSS to detect <b>community acquired pneumonia</b> (CAP) and <b>heart failure</b> (HF) and then to improve compliance with national quality indicators.	<b>Before and after study. 7</b> months pre and post implementation of CCDSS. Before and after comparison for quality indicators. No sample sizes were available despite email correspondence with the author	CAP <ul style="list-style-type: none"> <li>• Antibiotics within four hours</li> <li>• Pneumococcal vaccination status documented</li> <li>• Appropriate antibiotics HF</li> <li>• Left ventricular (LV) function assessment</li> <li>• Initiation of medication</li> <li>• Provision of discharge instructions</li> </ul>	Measures of antibiotic administration within 4hrs and vaccination status recording slightly increased.  Correct antibiotic selection decreased slightly – none were statistically significant. LV function assessment and medication initiation increased slightly but were not statistically significant.  Provision of discharge instructions for HF increased (p<0.01)

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Roy, Durieux, Gillaizeau, Legall, Armand-Perroux, Martino, Hachelaf, Dubart, Schmidt, Cristiano, Chretien, Pierrier & Meyer (2009). France	Assessing the effectiveness of a hand held CCDSS of improve the diagnostic work-up of patients with suspected <b>pulmonary embolism</b> .	<b>Cluster RCT</b> . After all 20 EDs were accustomed to inputting clinical data and using the devices they were randomly allocated to either activation of the CCDSS on the device or posters and pocket cards that showed the validated diagnostic strategies. Pre-intervention (20 centres) 1103 patients. Post intervention. 10 centres randomised to CDDSS (n=753). 10 centres to posters and pocket cards (n=1052).	Primary outcome was appropriateness of diagnostic work-up in each centre	Appropriate workups increased in all patients in comparison to before the trial began. However the greatest increase was in the CCDSS. Primary outcome was appropriateness of diagnostic workup, this increased by 19.3% after adjusting for variables (p=0.023). Pre-test probability scoring was greater in the CCDSS (p<0.001).
Buising, Thursky, Black, MacGregor, Street, Kennedy & Brown (2008). Australia	To evaluate the impact of 2 methods of guideline implementation; (academic detailing, CCDSS) on prescribing for patients with <b>community acquired pneumonia</b> .	A two stage <b>before and after intervention cohort study and a time series analysis</b> .  All patients that presented during the study period (baseline n=392, academic detailing n=215 & CCDSS n=133) were compared for concordance with recommendations on prescribing.	<ul style="list-style-type: none"> <li>• The prescription of antibiotic that adequately covered likely pathogens and followed recommendations.</li> <li>• Recognition of severely ill and adjustment of antibiotics.</li> <li>• Adjustment of antibiotics for allergies</li> </ul>	There was an improvement in antibiotic prescribing with both academic detailing and CCDSS. However the improvement in prescribing with the CCDSS was greater than expected to have occurred based on binary logistic predictions.

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Roukema, Steyerberg, van der Lei & Moll (2008). Netherlands	To assess the compliance with a CCDSS for the management of <b>children with fever</b> without an apparent source. To assess the effects on time in the ED and number of laboratory investigations ordered.	<b>Prospective RCT.</b> 164 children in total.  n=74 randomised into CCDSS group which gives immediate instructions on what laboratory investigations to order.  n=90 randomised to “usual care” assessed by a physician who then decided on the investigations	<ul style="list-style-type: none"> <li>• Compliance with CCDSS</li> <li>• LOS in ED</li> <li>• Number of investigations ordered</li> </ul>	<p>Length of time in ED was no different between the two groups. This was an unexpected result. Adherence to the advice from the CCDSS was deemed successful. Intervention group 82% had investigations ordered. In the control 44%. This is in contrast to expectations.</p> <p>The prediction rule in the CCDSS needed adjustment as was not specific enough to discriminate between children at high risk of serious infection. The CCDSS was discontinued.</p>
Asaro, Sheldahl & Char (2006) United States	What is the effect of the introduction of a CCDSS on guideline adherence for patients presenting with <b>Acute Coronary Syndrome</b> (ACS).	<b>Descriptive retrospective before and after study.</b> (4 phases)  1) pre CPOE, pre-printed order form available (n=45) 2) pre-CPOE several weeks after introduction of paper guideline (n=66) 3) several weeks after CPOE introduction (n=25) 4) 3 months after CPOE with additional education about the order sets (n=16)	<ul style="list-style-type: none"> <li>• Risk stratification; Acute ST elevation myocardial infarction, high-risk ACS, intermediate risk ACS &amp; low-risk ACS.</li> <li>• Drugs appropriately prescribed; <math>\beta</math>-blocker, heparin, aspirin.</li> </ul>	No improvement to overall compliance with any of the ACS recommendations.

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Goergen, Fong, Dalziel & Fennessy (2006). Australia	To assess if the introduction of an imaging guideline based on NEXUS criteria can reduce the numbers of radiological investigations in patients with <b>neck trauma</b> in the ED. The imaging guideline was converted into CCDSS.	<p><b>Before and after study.</b> Prospective non-randomised clinical trial (October 2001-September 2002) using historical controls (June 2000-July 2001)</p> <p>Study group n=353</p> <p>Control n=403. Of the 353 study patients 141 were managed with the CCDSS (40%)</p>	<ul style="list-style-type: none"> <li>• How many used the CCDSS.</li> <li>• Of those managed with CCDSS that advised no x-ray, how many were not x-rayed</li> </ul>	<p>Statistically significant reduction in the number of neck images (<math>p=0.03</math>) in the total sample.</p> <p>Largest reduction was in those patients managed with the CCDSS (<math>p=0.01</math>).</p> <p>There was no delayed diagnosis in those not imaged.</p>
Dong, Bullard, Meurer, Colman, Blitz, Holroyd & Rowe (2005). Canada	To determine the agreement between a computer-based <b>triage</b> tool and memory-based triage (the usual triage method).	<b>Prospective observational study.</b> 693 patients were triaged in the usual way (memory-based) and then by a blinded research nurse using the computer-based tool. The results of both triage decisions were compared. An expert panel were used to judge the accuracy of both decisions.	<ul style="list-style-type: none"> <li>• To determine agreement between CCDSS for triage and usual care</li> </ul>	<p>Agreement between the computer-based triage system and the usual memory-based system was poor.</p> <p>There was more agreement between the expert panel and the computer-based system than the expert panel and the memory-based system.</p>

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Schriger, Bareff, Buller, Shendriker, Nagda, Lin, Mikulich & Cretin (2000), United States	Assessing the effects of guidelines incorporated into an electronic patient record (EPR) for <b>children under 3 years with fever</b> in guideline adherence.	Prospective off-on-off <b>interrupted time series</b> with intent to treat analysis. Phase 1 Off n=352. Phase 2 On n=374. Phase 3 Off n=104	<ul style="list-style-type: none"> <li>• Quality of clinical documentation</li> <li>• Provision of aftercare instructions</li> </ul> Appropriateness of <ul style="list-style-type: none"> <li>• Testing</li> <li>• Treatment decisions</li> <li>• Diagnosis</li> </ul> <ul style="list-style-type: none"> <li>• Overall cost of care</li> </ul>	Quality of documentation improved from 80% to 92% between Phase 1 & 2 (13% improvement 95% CI, 10–15). Documentation of after-care instructions improved from 48% to 81% between Phase 1 & 2 (33% improvement 95% CI, 28–38). All documentation returned to the baseline during Phase 3. No difference in appropriateness of care. No change in cost of care.
Day, Linh, Hoang, Ouk, Nagda & Schriger (1999). United States	Does use of a CCDSS for <b>acute low back pain</b> improve guideline adherence.	Prospective <b>time series</b> on/off design. Paper versus CCDSS for acute low back pain. Control (n=206), random sample of 103 charts analysed. Test period n=259. n=202 were treated with the CCDSS. All 259 were analysed.	<ul style="list-style-type: none"> <li>• Accurate documentation,</li> <li>• Discharge instructions given</li> <li>• Investigations ordered</li> <li>• Treatment</li> <li>• Patient disposition.</li> </ul>	Statistically significant improvement in documentation (p<0.001) and discharge instructions (p<0.001). There was no statistically significant difference between x-rays ordered, medication use and cost of care.

Author and country	Aim of Study & Clinical condition	Study design and sample	Key outcome measures	Results
Schriger, Baraff, Rogers & Cretin (1997). United States	Assessing effects of guidelines incorporated into an EPR for <b>health care workers exposed to body fluids</b> on guideline adherence	Prospective 3 phase off-on-off <b>interrupted time series</b> with intention to treat analysis. Phase 1. Off n=50, Phase 2. On n=156, Phase 3. Off n=74.	<ul style="list-style-type: none"> <li>• Quality of care as determined by 7 essential items documented in the medical record</li> <li>• Provision of aftercare instructions.</li> <li>• Compliance with 4 testing decisions</li> <li>• Compliance with 5 treatment decisions</li> <li>• Overall costs of care</li> </ul>	Documentation improved by 42% (95% CI 34-49%) between phase 1 & 2 but decreased to baseline in phase 3. Compliance with issuing aftercare instructions increased by 62% (95% CI 51-74%) but decreased to baseline in phase 3. Compliance with laboratory testing increased by 20% (95% CI 9%-31%) and decreased to below baseline in phase 3. Compliance with treatment increased by 13% (95% CI 9%-17%) and decreased to baseline in phase 3. Charges incurred for test and treatments increase by 37% (95% CI 22-52%) and decreased below baseline in phase 3.

#### *3.4.1 Country of origin and ED setting*

Sixty percent of the studies were undertaken in the US (n=14), the remainder in Canada (n=3), Australia (n=3), UK (n=1), France (n=1) and the Netherlands (n=1). The majority of studies tested the CCDSS in one ED (n=18). There were four multi-centre studies: 2 in the US which evaluated the same CCDSS in four EDs, a Canadian study in four EDs and finally a study in France with 20 EDs. The vast majority of studies were undertaken in academic emergency departments (n=21). Where the studies were multi-centre (n=4) the lead investigators were from academic departments.

Seventeen of the studies took place in Level 1 trauma centres. National systems for managing patients with multiple trauma were first developed in the US (American College of Surgeons, 2014). EDs with Level 1 trauma status are specifically designated to receive adults and/or children with multiple injuries because of the range and extent of specialties on site. Patients who are multiply injured are taken to the nearest Level 1 trauma centre, which may mean bypassing another hospital.

With the exception of France the other countries represented in the selected studies - Canada, Australia, UK and the Netherlands - all have similar regional trauma systems. The UK's major trauma system was the most recently implemented in 2012 (DH, 2014). EDs that assess and treat patients with major trauma are required to have 24 hour ED Consultant presence (American College of Surgeons 2014 & DH 2014). This ensures that they are always adequately staffed to meet the needs of trauma patients. The next section identifies each researcher's rationale in the included studies for the implementation and subsequent evaluation of their CCDSS in an ED.

#### *3.4.2 Rationale for undertaking CCDSS research*

All of the studies refer to the challenges of guideline adherence in an era where there is rapid expansion of clinical guidelines, quality indicators, risk assessment tools and core measures for specific clinical conditions. There is wide disparity

between what clinicians should do in clinical practice and what they actually do (Lim et al 2012). The methods that have been traditionally used for the dissemination of guidelines or clinical practice standards - posters, paper guidelines, educational interventions - have had little effect (Busing et al 2008). Several papers quote the unique challenges of the ED environment: multiple interruptions, complex patients, overcrowding indicating that these add considerably to the difficulties of guideline implementation (Bond et al 2013, Dexheimer et al 2013, Gibbs et al 2012, Kwok et al 2009 & Nelson et al 2011). Several authors cited the need to control costs and/or increase revenue by meeting quality indicators as a driver for CCDSS implementation and research (Drescher et al 2011, Raja et al 2012 & Niemi et al 2009). Two studies evaluated the role of CCDSSs for the management of patients with sepsis. They cited the critical nature of the condition, its improved mortality and morbidity with prompt treatment and its challenge to diagnose as reasons for exploring the impact of CCDSS for its management in ED (Bond et al 2013 & Nelson et al 2011). Fifty six percent of the studies (n=13) cover five clinical conditions: pulmonary embolism (PE), community acquired pneumonia (CAP), asthma, fever in children and sepsis (Bond et al 2013; Busing et al 2008; Dexheimer et al 2013; Drescher et al 2011; Gibbs, et al 2012; Jones et al 2013; Kwok et al 2009; Nelson et al 2011; Niemi et al 2011; Raja et al 2012; Roy, et al 2009 (Schriger et al., 2000; Roukema, Steyerberg, van der Lei, & Moll, 2008). These are all common conditions with clear evidence-based guidelines but there is persisting evidence of poor compliance (Sheldon et al., 2004). The consensus within the selected studies is that CCDSSs provide an encouraging means of improving the quality of ED patients' care. Some departments were reported to be so encouraged by the results that they developed additional CCDSSs for other conditions - these generated several further studies, as summarised in the next section.

### *3.4.3 EDs that have generated more than one CCDSS research study*

Three academic EDs have been researching several different CCDSSs and have generated more than one research paper in the selected studies. The University Hospital of Alberta, Canada has reported on three studies between 2005 and 2013



(Dong et al., 2005; Lim et al., 2012; Bond et al., 2013). These studies consider the impact of CCDSS on sepsis management in ED, emergency triage and febrile neutropenia. Maine Medical Centre in the US conducted two of the included studies (Gibbs, Baumann, Lyden, Strout, & Knowles, 2012; Britton, Bloch, Strout, & Baumann, 2013). These studies assessed the impact of two separate CCDSSs on the care of victims of sexual assault (Britton et al., 2013) and CAP (Gibbs et al., 2012). Finally three studies were conducted at University of California Los Angeles (UCLA), emergency medical centre, US (Day, Hoang, Ouk, Nagda, & Schriger, 1995; Schriger, Baraff, Rogers, & Cretin, 1997; Schriger et al., 2000). These are several of the earliest studies in the literature review and they evaluate the decision support functions of a locally developed CCDSS. Day et al., (1995) assessed the impact of decision support within their system for acute low back pain. Schriger et al. (1997, 2000) used the same system and embedded decision support for the assessment and management of health care workers exposed to blood borne viruses and children under 3 years presenting with fever. In total a third of the included studies have been generated by three academic EDs. The next section gives an overview of the studies by identifying the clinical conditions subjected to CCDSS.

#### *3.4.4 Clinical conditions investigated*

There are a wide variety of clinical conditions studied: CAP and PE dominate, each with three studies. Sepsis, fever in children and asthma in children both have 2 studies. One CCDSS studied covered both heart failure and CAP. The remaining 10 studies include a wide variety of clinical conditions: acute coronary syndrome, sexual assault, soft tissue infection, acute low back pain, triage, neck trauma, pain in children, febrile neutropenia, syncope, and blood borne virus exposure. The next sections provide the final overview of the included studies by identifying the functionality of the systems in use.

### **3.5 Type of CCDSSs and their functionality**

Table 3.3 identifies the types of decision support used and how it provided guidance for the clinician e.g. pop-up alerts or emails. Four CCDSS were

incorporated into CPOE for acute coronary syndrome (n=1), sexual assault (n=1) and PE (n=2) (Asaro, Sheldahl , & Char, 2006; Drescher et al., 2011; Raja et al., 2012; Britton et al., 2013). These four systems all used an embedded order set to ensure that the right assessment, investigation and treatment took place. Several CCDSSs were locally developed but then incorporated into the existing commercial system used in the ED (Melnick et al., 2010; Drescher et al., 2011; Lim et al., 2012). Only seven CCDSSs were commercial, the majority being locally developed (n=19). The most common method of decision-support was via pop up alerts, which provided suggestions to the clinicians regarding assessment and or treatment options (n=12).

Table 3.3 Types of CCDSS in use in EDs and their functionality

Author & Clinical Condition	Commercial system	Locally developed	Embedded in CPOE	Mandatory	Decision-support via				
					Email	Pop-up alert	Pager	Embedded order-set	Other
Bond, Djogovic, Villa-Roel, Bullard, Meurer & Rowe (2013) <b>Sepsis</b>	X	✓	X	X	X	X	X	X	Prompts within CCDSS
Britton, Bloch, Strout & Baumann (2013) <b>Sexual Assault</b>	✓	X	✓	X	X	X	X	✓	Prompts within CPOE
Dexheimer, Abramo. Arnold, Johnson, Shy, Ye, Fan, Patel & Aronsky (2013) <b>Asthma in children</b>	X	✓	X	✓	X	X	X	X	Printed out paper guideline
Jones B, Jones J, Stoddard, Vines, Jephson, Ferrari, Post, Briggs, Griffin, Kumar, Allen, Haug & Dean (2013) <b>Community Acquired Pneumonia</b>	X	✓	X	?	?	?	?	?	No details available

Author & Clinical Condition	Commercial system	Locally developed	Embedded in CPOE	Mandatory	Decision-support via				
					Email	Pop-up alert	Pager	Embedded order-set	Other
Gibbs, Baumann, Lyden, Strout & Knowles (2012) <b>Community Acquired Pneumonia</b>	X	✓	X	?	?	?	?	?	No details available
Raja, Ip, Prevedello, Sodickson, Farkas, Zane, Hanson, Goldhaber, Gill & Khorasani (2012) <b>Pulmonary embolism</b>	X	✓	✓	✓	X	✓	X	✓	
Lim, Bawden, Wing, Villa-Roel, Meurer, Bullard & Rowe (2012) <b>Febrile neutropenia</b>	✓	✓ <sup>2</sup>	X	X	X	✓	X	X	
Carman, Phipps, Raley, Li & Thornlow (2011) <b>Skin/soft tissue infections</b>	✓	X	X	X	X	✓	X	X	Linked to CPOE for ordering swabs

Author & Clinical Condition	Commercial system	Locally developed	Embedded in CPOE	Mandatory	Decision-support via				
					Email	Pop-up alert	Pager	Embedded order-set	Other
Drescher, Chandrika, Weir, Weintraub, Berman, Lee, Burskirk, Wang, Adewunmi & Fine (2011) <b>Pulmonary Embolism</b>	✓	✓	✓	✗	✗	✓	✗	✓	
Nelson, Smith, Jared & Younger (2011) <b>Sepsis</b>	✗	✓	✗	✗	✗	✓	✓	✗	Automatic ally generated text suggesting treatment
Melnick, Genes, Chawla, Akerman, Baumlin & Jagoda (2010) <b>Syncope</b>	✓	✓	✗	✗	✗	✗	✗	✗	
Jadav, Lloyd, MacLauchlan & Hayes (2009) <b>Pain in children</b>	✓	✗	✗	✓	?	?	?	?	No details available
Kwok, Dinh, Dinh, Chu (2009) <b>Asthma in children</b>	✗	✓	✗	✗	✗	✓	✗	✗	

Author & Clinical Condition	Commercial system	Locally developed	Embedded in CPOE	Mandatory	Decision-support via				
					Email	Pop-up alert	Pager	Embedded order-set	Other
Niemi, Geary, Quinn, Larrabee & Brown (2009) <b>Community Acquired Pneumonia and Heart Failure</b>	X	✓	X	X	✓	✓	X	X	Emails and printed alerts sent to various places
Roy, Durieux, Gillaizeau, Legall, Armand-Perroux, Martino, Hachelaf, Dubart, Schmidt, Cristiano, Chretien, Pierrier & Meyer (2009) <b>Pulmonary Embolism</b>	X	✓	X	X	X	✓	X	X	
Buising, Thursky, Black, MacGregor, Street, Kennedy & Brown (2008) <b>Community Acquired Pneumonia</b>	X	✓	X	X	X	✓	X	X	Prompts within CCDSS

Author & Clinical Condition	Commercial system	Locally developed	Embedded in CPOE	Mandatory	Decision-support via				
					Email	Pop-up alert	Pager	Embedded order-set	Other
Goergen, Fong, Dalziel & Fennessy (2006) <b>Neck trauma</b>	X	✓	X	X	X	X	X	X	CCDSS, advised if x-ray required
Dong, Bullard, Meurer, Colman, Blitz, Holroyd & Rowe (2005) <b>Triage</b>	X	✓	X	✓	X	X	X	X	The CCDSS presents the triage guideline
Schriger, Bareff, Buller, Shendriker, Nagda, Lin, Mikulich & Cretin (2000). <b>Fever in children &lt;3yrs</b>	X	✓	X	X	X	✓	X	X	
Day, Linh, Hoang, Ouk, Nagda & Schriger (1999) <b>Acute low back pain</b>	X	✓	X	X	X	X	X	X	Prompts with CCDSS suggesting treatment
Schriger, Baraff, Rogers & Cretin (1997) <b>Blood borne virus exposure</b>	X	✓	X	✓	X	✓	X	X	

### **3.6 Review of the methodological quality of the included studies**

The remainder of this chapter critically appraises the research methods used in the included studies. Critical appraisal of the CCDSS research in EDs has been undertaken for several principal reasons:

- To determine the quality of the studies in order to identify the strength of the current evidence and the degree of confidence that can be given to the results.
- To consider the methodological issues concerning CCDSS research in EDs in order to inform this study.

During the initial appraisal of the studies it became apparent that a wide array of descriptions was used to define the research methods. Initially this was confusing; the authors gave the studies a label, which was not always indicative of the research method employed. For example, Goergen et al. (2006) described their study as a prospective non-randomised controlled trial and Kwok et al. (2009) described theirs as an observational study using a pre and post intervention design. As is often the case these descriptors do not adequately or universally describe the fundamental design features of the research (Higgins & Green, 2011). To make the actual methods used more obvious the included studies have been grouped together under the following five research design headings. This has also enabled an appraisal of methods as these headings more clearly describe the main features of the research design

Five research designs have been used in the included studies, they are:

1. Randomised controlled trial (n=3) 13%
2. Before and after study (B&A) (n=13) 57%
3. Interrupted times series (n=5) 22%
4. Prospective observational design (n=1) 4%



## 5. Comparative cohort design (n=1) 4%

### *3.6.1 Approach to the methodological review of the studies*

A distinct approach has been taken regarding the methodological assessment of the included studies. In order to consider the strength of the current evidence the three predominant research designs will be considered firstly, in turn: RCT, B&A study and interrupted time series (ITS). Each design has its own strengths and limitations when used to evaluate CCDSSs. The studies that have used each design may also vary in quality depending upon how rigorously the design was applied. There is an increasing body of literature challenging the approaches used to evaluate CCDSS. These researchers also describe methods they view as appropriate for assessing the effectiveness of CCDSSs (Randolph, Haynes, Wyatt, Cook, & Guyatt, 1999; Aronsky, Chan, & Haug, 2001; Eccles, Grimshaw, Campbell, & Ramsay, 2003; Harris et al., 2006; Brown & Lilford, 2008; Shcherbatykh, Holbrook, Thabane, & Dolovich, 2008; Liu & Wyatt, 2011; Augestad et al., 2012). The next two sections draw on this methodological literature and consider the relative values of different research designs. Several of the included studies are referred to in this discussion as part of the more general methodological overview.

### *3.6.2 Randomised controlled trials as a method for investigating CCDSSs*

RCTs are considered the “gold standard” for reporting the effects of interventions (Guyatt, Sackett, Sinclair, & et al., 1995). Well conducted RCTs eliminate the effects of confounding variables and are regarded as the most definitive means of establishing cause and effect (Liu & Wyatt, 2011). Advocates of this method for the evaluation of health informatics state that the RCT is best placed to answer questions regarding the effect a CCDSS has on changing practice or improving patient outcomes (Haynes & Wilczynski, 2010; Liu & Wyatt, 2011). However the evaluation of an informatics system in a busy clinical environment can be fraught with the methodological challenges that executing an RCT poses (Shcherbatykh et al., 2008). For example appropriate blinding methods, an adequate sample size and complete follow-up, all seen as key to internal validity can be difficult to

implement in clinical practice (Shcherbatykh et al., 2008). A recent systematic review assessed the quality of RCTs used in CCDSS research against the CONSORT guidance for RCTs (Augestad et al., 2012). Of the 32 studies in the review the overall quality was deemed low. For example only 15% (n=5) of the studies had adequate blinding (Augestad et al., 2012). The authors conclude that there is a need to develop consensus guidelines for the standard expected of RCTs when they are used to evaluate the impact of medical informatics systems.

Despite the assertions in the literature regarding the superiority of the RCT as a method and its feasibility in CCDSS research only 3 of the included studies in this literature review utilised this design (Roukema et al., 2008; Roy et al., 2009; Dexheimer et al., 2013).

Lui & Wyatt (2011) identified that only 6.7% of information system studies conducted between 2006-2010 were RCTs. This suggests that although RCTs are purported to be a suitable method for informatics research, the challenges they pose in the field may cause many researchers to reject them.

Other researchers consider alternative methods as an appropriate means by which to investigate the impact of CCDSSs (Campbell, M. et al., 2000; Eccles et al., 2003; Brown & Lilford, 2008). These will be explored in the next section.

### *3.6.3 Non-experimental designs used to investigate CCDSSs*

CCDSSs are considered to be a complex intervention to implement as they fulfil the criteria developed by Campbell et al., (2000). A complex intervention is one that consists of many related aspects, some or all of which require evaluation (Campbell, M. et al., 2000). In CCDSS research patient outcomes and practitioner behaviours are often the target of the investigation and in a busy, unpredictable clinical environment they can be difficult to implement, monitor and organise (Shcherbatykh et al., 2008). There is some consensus in the literature which suggests a suite of alternative research methods can be used to effectively measure the impact of CCDSSs (Campbell, M. et al., 2000; Aronsky et al., 2001; Eccles et al., 2003; Harris et al., 2006; Brown & Lilford, 2008; Shcherbatykh et al.,

2008). They are: uncontrolled B&A studies, controlled B&A studies and ITS designs. Often a pragmatic approach has to be adopted due to the constraints within the clinical environment or the intricacies of the intervention (Harris et al., 2006). These additional methods offer an alternative when an RCT is not feasible or acceptable (Craig et al., 2008).

In addition to the methodological debates in the literature about the most appropriate ways to investigate the effect of CCDSSs the Cochrane Collaboration gives further insight. The Cochrane Collaboration Effective Practice and Organisation of Care Group (EPOC) (EPOC, 2012) develop systematic reviews that identify effective interventions that improve the delivery of care. Research into CCDSSs is considered an appropriate focus of research for this Cochrane group. The EPOC Group have developed specific criteria for the inclusion of studies based on the study's design (EPOC, 2013b). They concur with those researchers who advocate the use of methods additional to the RCT and suggest four study designs for inclusion in their reviews: RCTs, non-randomised controlled trials, controlled B&A studies and ITS studies. Additionally the EPOC Group have developed detailed guidance on assessing the quality of each of the above designs for their risk of bias (EPOC, 2013a). In applying a rigid systematic review methodology Cochrane reviews have established themselves worldwide as a reliable and credible source of evidence about the effectiveness of interventions. It is on this basis that the EPOC Groups guidance has been used where relevant to aid in the assessment of the quality of the included studies and in particular whether they are free from bias. The next section critically appraises the RCTs included in this literature review using the EPOC criteria for randomised designs.

### **3.7 Randomised controlled trials that have assessed the use of CCDSSs in EDs**

There are three studies that have used a RCT design (Roukema et al., 2008; Roy et al., 2009; Dexheimer et al., 2013). The studies by Roukema et al (2008) and Dexheimer et al (2013) were both conducted in Paediatric Academic EDs. The study by Roy et al (2009) was a cluster randomised controlled trial across 20 EDs in France, approximately half of which were academic departments. The basis for

the use of RCTs in health care research is that the random allocation of participants manages potential bias. When considering the risk of bias in CCDSS studies researchers are concerned with developing a research method that isolates the effects of the CCDSS from any other influences. Randomising participants spreads known or unknown confounding variables equally between the control and experimental groups (Greenhalgh, 2010). The EPOC Group identify nine criteria against which to judge the risk of bias for studies with a separate control group see Table 3.4 (EPOC, 2013a). Several of these criteria are used to illustrate the methodological issues of the included RCTs in EDs.

Table 3.4 EPOC criteria for assessing risk of bias (EPOC, 2013a)

1.	Was the allocation concealment adequately generated?
2.	Was the allocation adequately concealed?
3.	Were baseline outcome measurements similar?
4.	Were baseline characteristics similar?
5.	Were incomplete outcome data adequately addressed?
6.	Was knowledge of the allocated interventions adequately prevented during the study?
7.	Was the study adequately protected against contamination?
8.	Was the study free from selective reporting?
9.	Was the study free from other risks of bias?

Before proceeding to examine the Cluster RCT by Roy et al., (2009) the RCTs by Roukema et al., (2008) and Dexheimer et al., (2013) will be critically appraised. These two studies randomised children into either the control or intervention arm of the trial after the initial triage assessment. In practice this would mean that at any one time children could be in the ED, with the same condition, being

managed in different ways by the same or different staff. In the study by Dexheimer et al., (2013) children with asthma were identified by the CCDSS and then randomised to the control group or the intervention group. Those in the intervention group had the clinical guideline for asthma management printed out at the end of the triage assessment for use by the clinician. However all the physicians were aware of the study and the newly developed asthma guideline was in poster format in several places in the ED. It could be argued that this is “usual care” as most EDs have guidelines available in paper or electronic format.

Similarly in the study by Roukema et al., (2009) children with fever and a high risk of serious bacterial infection were randomised to the control group or the intervention group. For those in the intervention group the nurses received immediate instructions regarding what investigations to order. Subsequent assessment by the physician would reveal which group the child had been randomised to, as investigations would already have been ordered. Both of these randomisation approaches make isolating the impact of the CCDSS from other influencing factors that would alter physician behaviour impossible. It is possible that the physician’s behaviour in either study would be affected by their exposure to the intervention group. The care of all children presenting to the EDs with asthma or fever could improve as a result of the physicians contact with the clinical guidelines when assessing children in the intervention groups.

Assessing this one element of risk of bias against the EPOC criteria in Table 3.4 above reveals that in these two studies lack of blinding (6) and lack of protection against contamination (7) are likely to create a high risk of bias (Higgins et al., 2011). In the study by Dexheimer et al., (2013) there was no statistically significant difference between the control and intervention groups. This could have been due to cross contamination and the availability of the clinical guideline for all clinicians. In an ED setting, when randomising at an individual patient level there will always be the inherent risk of the clinician remembering patient management. When there is a probability of secondary benefit of the intervention to the control group evidence of the true effect of the CCDSS will be unclear (Chuang, Hripcsak, & Heitjan, 2002). This is likely to result in an

underestimation of the effect of the CCDSSs (Shcherbatykh et al., 2008; Liu & Wyatt, 2011).

Cluster RCTs are better placed to manage the contamination that results from the physician's experience of using the intervention and the effect this may have on the control group (Eccles et al., 2003). The cluster RCT by Roy et al., (2009) randomised 20 EDs across France to either control or intervention departments. This had the effect of not only randomising the departments but all the medical staff within them and eliminating any performance bias during the course of the study (Higgins et al., 2011). Cluster RCTs are complex and expensive to implement and the cost and effort required often makes them impractical to implement (Eccles et al., 2003; Liu & Wyatt, 2011). This is the most likely reason why there is only one in the selected studies.

The design of the cluster RCT by Roy et al., (2009) eliminated many of the risks of bias seen in the other RCTs. EDs were randomised with a random number generator to either the control EDs (paper/pocket guideline) or intervention EDs (use of the handheld CCDSS). Randomisation was stratified to include 5 centres, each with high and low proportions of appropriate diagnostic workups during the pre-intervention period. Baseline assessment of performance enables stratification and eliminates the risk of clustering the poorer performing EDs into either control or intervention (Eccles et al., 2003). The choice of this method alone is likely to reduce the risk of selection, performance and detection bias (Higgins et al 2011). Interestingly real-time use of the CCDSS was low at 40% (Roy et al., 2009). When data was not entered into the CCDSS it was extracted from the clinical notes within 72hrs. How this was done and by who was not reported. Overall the quality of this study was high and this risk of bias was low. However it is unlikely that cluster RCTs are a feasible option for most CCDSS researchers due to the high cost and logistical challenges of implementation.

The overall lack of robust RCTs undertaken to evaluate CCDSSs in EDs is evident from this literature review. Complexities within the clinical environment create research design challenges and these may be difficult to overcome with limited

resources (Aronsky et al., 2001). The asthma detection and management system evaluated by Dexheimer et al (2013) did not demonstrate any benefits. Roukema et al (2008) did demonstrate an improvement in the adherence to the CCDSS advice for children with fever. However the CCDSS was discontinued due to its inability to discriminate between children with low or high risk of serious infection. In conclusion the cluster RCT by Roy et al (2009) is the only study using a randomised experimental design that demonstrates tangible improvements in the process of care.

RCTs were small in number in this review. The most common design adopted for CCDSS research is EDs are B&A studies; these studies will now be reviewed

### **3.8 Before and after studies that have assessed the use of CCDSSs in EDs**

B&A studies are the predominant design identified in this literature review. They are also the leading research method in the general CCDSS research (Liu & Wyatt, 2011). Due to the frequency of this design in the general CCDSS research and within this literature review an in-depth appraisal of this design and the studies using it follows. This will inform the methodological approach for the study in this thesis and enable the strength of the evidence of the studies using this design to be assessed.

B&A studies are a relatively easy research method to develop and implement when a new CCDSS system is introduced. Researchers concerned with understanding the impact of the CCDSS firstly take measurements before the system change/implementation. This “before”, “pre-intervention” or “pre-test” group are also referred to as historical controls in some studies and provide a baseline measure before the CCDSS is introduced (Grimshaw, J, Campbell, Eccles , & Steen, 2000). At some time after the implementation the same measures are taken again. A comparison between the results is then analysed to identify the degree of difference.

There are two main types of B&A study in the general literature; controlled and uncontrolled (Grimshaw, J et al., 2000). An uncontrolled B&A study is a commonly

used design and is described above. A “before” measure is taken, the intervention is implemented and an “after” measure is taken. Any change is assumed to have occurred because of the intervention (Harris et al., 2006). In a controlled B&A study a matched control group is identified and measurements from this group are also taken before and after (Cochrane, n.d.). The control group is measured at the same time intervals before and after the implementation of the intervention but is never exposed to it (Harris et al., 2006).

Four of the included B&A studies describe the use of a “control” (Goergen et al., 2006; Kwok, Dinh, Dinh , & Chu, 2009; Melnick et al., 2010; Bond et al., 2013; Hoffmann et al., 2014). In these studies the terms “retrospective’ or “historical” control are used purely to define the pre-intervention comparison groups; they are not in fact matched controlled groups that are measured both before and after the intervention. Bond et al., (2013) used historically matched controls in their research into sepsis management before and after the introduction of an alerting decision-support tool. 51 patients with sepsis were matched by age and gender with 51 controls. None of the B&A studies used a true controlled B&A design as defined in the literature primarily because the control group is not measured before and after the intervention. A true controlled B&A study would not be possible in an ED setting as the control group could not be easily revisited again. All the included studies should be regarded as using an uncontrolled B&A method. One of the included B&A studies was identified by its conference abstract (Jones, B. et al., 2013). Despite email contact with several of the authors no further details have been made available. The analysis of the quality of this study is therefore very limited.

### *3.8.1 Approach to the critical appraisal of the before and after studies*

When considering the EPOC Group (2013b) criteria for including different study designs in their systematic reviews uncontrolled B&A studies are discounted. The EPOC Group (2013a) asserts that when B&A studies only contain one control (the before) any identified change cannot be wholly attributed to the intervention. Unknown variables may exist between the two groups being compared that are in



fact causing the difference. For this reason the EPOC Group (2013b) completely reject the inclusion of any uncontrolled B&A studies in their reviews.

However, appraisal of the thirteen included studies using this design is still warranted due to their frequency; more than half of the included studies that have evaluated CCDSSs in EDs have used a simple B&A design. It has been suggested that non-experimental designs can have a role in providing preliminary evidence for effectiveness (Robson, Shannon, Goldenhar , & Hale, 2001). Indeed the Cochrane Collaboration recognise that in some areas where RCTs are difficult to execute the inclusion and appraisal of non-randomised studies is warranted (Higgins & Green, 2011) There are no recognised appraisal tools for the evaluation of non randomised designs or more specifically uncontrolled B&A studies. The following appraisal of the strengths and weakness of these studies has been developed from Cochrane and other resources used for the detection of bias in experimental and non-experimental studies and are described in Table 3.5 below (Robson et al., 2001; Higgins et al., 2011; Higgins & Green, 2011). Each threat to bias is described in turn and its impact on included studies is analysed.

Table 3.5 Threats to internal validity in uncontrolled before and after studies developed from (Higgins et al., 2001, Higgins & Green, 2011 & Robson et al., 2001)

1. Selection bias
2. Performance bias
  - a. Historical changes
  - b. Testing bias
  - c. Hawthorne effect
  - d. Maturation effect
3. Detection bias
4. Attrition bias
5. Reporting bias
6. Regression to the mean
7. Confounding variables

### *3.8.2 Selection bias in before and after studies*

The non-random selection of participants in a B&A method creates bias as each group will not have an equal representation of the same known and unknown

confounders (Bruce, Pope , & Stanistreet, 2008). Few studies compared the characteristics of the control and interventions groups. Goergen et al., (2006) did compare each group by age, gender and injury severity, which seems appropriate in a study on the effect of CCDSSs for radiological investigation in neck injury. However they did not use a validated tool to assess injury severity and therefore the degree of homogeneity between the groups is unclear. They did identify that the participants in the intervention group were older. This is a relevant finding as there is an increased tendency to x-ray the neck of an older person. This study did reveal a statistically significant difference in the numbers of x-rays ordered post intervention. However, the size of the effect cannot be relied upon because of this potential bias.

### 3.8.3 Performance bias in before and after studies

The identification of performance bias is concerned with identifying if those involved in the study knew about their participation as this may have changed their behaviour. In B&A studies the factors to consider with regard to the changing behaviour of participants are: historical changes, testing bias, Hawthorne effect and maturation effect. In uncontrolled B&A studies there is no “blinding” of study participants but an equivalent is when patients and clinicians are unaware the study is taking place. This is relatively easy to achieve in this design as outcome data is often extracted retrospectively from the clinical record. In the studies by Asaro et al., (2006), Jadav et al., (2009), Melnick et al., (2010) and Bond et al., (2013) there was no awareness of the research in the ED. However in the studies by Carman, Phipps, Raley, Li & Thornlow (2011) & Drescher et al., (2011) the ED physicians knew that the study was taking place. In the remainder of the studies there was no mention of whether the ED staff and or patients were aware of the research (Goergen et al., 2006; Kwok et al., 2009; Niemi, Geary, Quinn, Larrabee , & Brown, 2009; Nelson, J., Smith, Jared , & Younger, 2010; Nelson, J, Smith, Jared , & Younger, 2011; Raja et al., 2012; Jones, B. et al., 2013).

In the evaluation of the impact of a CCDSS on the management of skin and soft tissue infections the clinicians involved were aware of the study (Carman et al., 2011). One week before the launch of the CCDSS the clinicians were sent a questionnaire to establish their understanding of infection prevalence and prescribing practices. This creates two areas where the risk of bias needs to be assessed: performance and testing. There will be the possibility that the performance of these clinicians altered for reasons other than the introduction of the CCDSS. Firstly they knew the study was taking place, this may have sensitised them to the management of patients with skin infections as they knew their management was under scrutiny – the so-called Hawthorne effect (Robson et al., 2001). Secondly, these physicians have been subject to a testing threat as they had already received a questionnaire about the management of these patients. One has to consider whether the CCDSS affected their clinical decision-making in any way. The questionnaire could have had a similar effect, different or opposite effect (Robson et al., 2001). Both these situations affect the confidence with which a conclusion can be drawn about the impact of the CCDSS in this study.

The historical changes that occur during the life of a study could have an unknown impact on clinician behaviour. Several studies comment on training or teaching sessions that took place when the new clinical guideline (that was part of the CCDSS) was introduced (Asaro et al., 2006; Drescher et al., 2011). Others commented that the guideline was available in paper format as well as being incorporated into the CCDSS (Asaro et al., 2006; Goergen et al., 2006). In one of the studies assessing the impact of a CCDSS on early sepsis care the authors comment that there was always a considerable amount of research into sepsis in the ED under investigation (Nelson, J et al., 2011). Niemi et al., (2009) stated that the CCDSS intervention in their study was part of multiple methods used to improve compliance with pneumonia and heart failure quality indicators. All these factors contribute to weakening any inference in a B&A study that can be made directly attributing any change in outcome to the CCDSS alone.

Finally clinician performance can simply change over time i.e. the maturation threat (Robson et al., 2001). B&A studies, by their design are conducted over a

longer period of time than studies using other methods (Bruce et al., 2008). For example the study by Raja et al., (2012) was conducted over a 6-year period. During this time span it is likely that there were several iterations of clinical guidelines with regard to the assessment and investigation of patients with possible PE. It may not be possible to isolate other effects from the impact of the CCDSS when studies are conducted over long periods.

#### *3.8.4 Detection bias*

In any study and particularly those using a non-randomised design there can be a tendency for researchers to discover and report the findings they are expecting (Higgins & Green, 2011). In B&A studies of CCDSS data is usually extracted from the clinical record. Several issues should be considered in assessing whether or not the process used for data extraction could introduce bias. Those extracting data from the records may or may not be:

1. blind to whether the results were from the pre or post intervention groups
2. blind to the study objectives and/or outcomes
3. the study researchers/designers of the CCDSS (with a vested interest in the results)
4. trained in the process of data extraction
5. using the same data extraction tool throughout the course of the study
6. dealing with data in different formats during the course of the study
7. assessed for the degree of agreement between them using inter-rater reliability testing

In the study by Goergen et al., (2006) two study nurses looked at the clinical records of patients, searching for any mention of neck injury. These were then included in the study. When a random sample of 20 patients were reviewed and there was 90% agreement between the nurses and the principle investigator. However, there were 756 patients in this study. A 20 patient random sample is only 2.6% of the total sample. There was no inter-rater reliability test to establish if this agreement could have happened by chance. A more robust approach was used by Kwok et al., (2009) in their study of the impact of a CCDSS on asthma

guideline adherence. Two research assistants were trained in data abstraction and were blind to the study objectives and outcomes. Any differences between them was resolved by discussion, however once again there was no inter-rater reliability testing. In a similar study assessing adherence to a national guideline for syncope using a CCDSS Melnick et al., (2010) did not train or blind their data extractors and again did not use any test of inter-rater reliability. Only one study tested the degree of consensus amongst four trained data extractors using a Cohen's Kappa Coefficient (Britton et al., 2013). No study considered or addressed all the possible causes of detection bias. When the process for the extraction of data is poorly constructed the robustness of the data and subsequent results are called into question (Higgins et al., 2011).

### *3.8.5 Attrition bias*

Attrition bias refers to the completeness of the data and whether any of it was missing (Higgins et al., 2011). When participants drop out of a study the control and intervention groups that were planned are now different (Robson et al., 2001). With regard to B&A studies in ED, the impact of the intervention is assessed over a relatively short period of time and therefore any dropout threat is negligible. However when patients require follow-up over a long period of time to identify any long-term outcome, those "lost to follow-up" may become an issue. In the study of neck imaging after trauma Goergen et al (2006) could not contact 13% of patients who did not have their neck x-rayed at 6 weeks. Although none of these patients returned to the hospital it remains unknown if they did subsequently have a neck fracture diagnosed elsewhere. A more significant risk with regard to the completeness of data is whether data is missing or that poor handwriting makes it difficult/impossible to reliably interpret. Several authors comment on missing data or handwriting that is indecipherable (Niemi et al., 2009; Drescher et al., 2011). When there are significant amounts of missing data the true effect of the intervention may be obscured because all the outcome data is not available for analysis (Higgins & Green, 2011).

### *3.8.6 Reporting bias*

Reporting bias is said to occur when only certain results/outcome measures are described (Higgins et al., 2011). Selective reporting of results relates to researchers including those results with statistical significance at the exclusion of other results showing no discernable impact with the intervention under investigation (An-Wen & Douglas, 2005). Reporting bias is a risk in all types of CCDSS research. Of the B&A studies only two took place in non-academic EDs; one was a locally developed system the other a commercial CCDSS (Jadav, Lloyd, McLauchlan, & Hayes, 2009; Drescher et al., 2011). The remaining 11 studies were all conducted in academic EDs, 73% (n=8) of which had a locally developed system (Goergen et al., 2006; Kwok et al., 2009; Niemi et al., 2009; Melnick et al., 2010; Nelson, J et al., 2011; Raja et al., 2012; Bond et al., 2013; Jones, B. et al., 2013). Of the 13 B&A studies five reported that some or all their outcome measures achieved no statistical significance (Asaro et al., 2006; Jadav et al., 2009; Niemi et al., 2009; Carman et al., 2011; Nelson, J et al., 2011). Two of these studies reported no overall improvement with any outcome measures (Asaro et al., 2006; Jadav et al., 2009). Carman et al., (2001) reported that only one secondary outcome measure improved. Niemi et al., (2009) & Nelson et al., (2011) both reported just one of their primary outcome measures that reached statistical significance.

The other B&A studies (n=8) presented overwhelming results demonstrating the success of their systems in terms of statistical significance (Goergen et al., 2006; Kwok et al., 2009; Melnick et al., 2010; Drescher et al., 2011; Raja et al., 2012; Bond et al., 2013; Britton et al., 2013; Jones, B. et al., 2013). There is some evidence to suggest that uncontrolled B&A studies may over-estimate the effects of an intervention (Grimshaw, J et al., 2000). There may be bias inherent within studies where the CCDSSs have been developed by the research team and tested in the ED where they work. How this would impact on the design, implementation, analysis and reporting of studies remains unclear.

### *3.8.7 Regression to the mean*

Regression to the mean is a well recognised concept in statistics which results in any observed change actually being due to chance rather than the intervention under investigation (Barnett, van der Pols , & Dobson, 2005). Regression to the mean is a significant threat in B&A studies. When one off measures are taken there is no way of knowing if this is within a normal range. If the “before” data actually reflects an extreme measurement, measurements will settle over time even without the intervention (Bland & Altman, 1994). Regression to the mean can threaten the internal validity of studies in health informatics (Harris et al., 2006). None of the B&A studies considered regression to the mean as a possible contributing factor in their results. Regression to the mean should always be considered and it should have been taken into consideration in the design and analysis of these studies (Barnett et al., 2005).

### *3.8.8 Confounding variables*

Finally the effect of confounding variables must be considered in all non-randomised research designs. When study subjects are randomised into control and intervention groups the effects of any confounding variables are controlled for (Bruce et al., 2008). Randomisation seeks to ensure that any known or unknown factors likely to have an impact on the study outcomes are spread equally between groups (Polit & Beck, 2008). Difficulty in measuring or controlling for confounding variables is a significant threat to the internal validity of a study (Harris et al., 2006). A confounding variable is one that is associated with the outcome of interest and may also be responsible for having an effect on it (Harris et al., 2006; Bruce et al., 2008). An important element of the quality assessment of informatics studies is to identify what confounders were present, whether they were recognised as a confounder and what was done to control for them (Higgins & Green, 2011). Confounding variables are either controlled by the design of the study or adjusted for as part of the statistical analysis (Bruce et al., 2008). When considering the presence of confounding variables in ED CCDSS

research, 4 have been identified from the literature review and are important to consider.

1. Patient characteristics: age, gender and in particular disease severity. How “sick” the patient was may alter management independently of the intervention
2. Clinician’s characteristics: when considering the effects of CCDSS on decision-making it is important to consider the experience level of those clinicians treating the patients in the study. This may have a significant effect on clinical decisions
3. Staffing levels: in studies that have assessed the timeliness of interventions e.g. time to antibiotics in patients with sepsis. Lack of staff to administer the treatment is a confounding factor
4. ED overcrowding: lack of staff, clinical/cubicle space or equipment e.g. infusion pumps may also affect the timeliness of interventions in studies where this is being measured.

An analysis of the confounding variables in the included B&A studies has revealed

- Some studies identified differences between the control and intervention groups during statistical analysis
- Some studies considered confounders at the outset of the study and commented on them
- Several studies considered confounders from the outset and used statistical techniques to adjust for confounders

Five studies did not discuss confounding variables in the design or analysis of the study (Asaro et al., 2006; Jadav et al., 2009; Niemi et al., 2009; Carman et al., 2011; Drescher et al., 2011; Nelson, J et al., 2011). The study by Jadav et al (2009) assessed whether mandatory pain scoring at triage would increase analgesia provision to children. No consideration was given to whether the child was assessed by an adult nurse or a children’s nurse as this may have been a significant factor in the administration of pain relief. Goergen et al (2006) did identify a significant difference in the ages of the control and intervention group.



However this was not recognised as a confounder despite the fact that there is a lower threshold of radiological examination in older patients (National Institute for Health Care Excellence, 2014). In one of the studies on sepsis care in ED the control and intervention groups were matched for age and sex (Bond et al., 2013). There was no statistical significant difference in triage priority, blood pressure, respiratory rate or temperature. However there was a difference in heart rate. Interestingly more of the intervention group were transferred to the intensive care unit, highlighting the severity of illness in that group.

Britton et al (2012) considered the age and gender of victims of sexual assault as a confounding variable as well as whether the assessing clinician was a sexual assault specialist nurse. There was no statistically significant difference between the control and intervention group for these features. Finally five studies assessed for the presence of confounding variables and adjusted their statistical analysis using regression models to account for them (Kwok et al., 2009; Melnick et al., 2010; Nelson, J et al., 2011; Raja et al., 2012; Jones, B. et al., 2013). Disease severity was addressed by Jones et al (2013) and Nelson et al (2011) and triage priority and clinician seniority by Kwok et al (2009). Age was seen as a confounder in the investigation of syncope and was adjusted for through multivariate analysis (Melnick et al 2010). Patient demographic and clinical characteristics were addressed through logistic regression in the study of CTPA ordering in PE (Raja et al 2012).

The presence, identification and subsequent management of confounders is a critical component in enhancing the internal validity of any non-randomised study (Harris et al., 2006). Where they are not considered and either addressed in study design through statistical analysis, their effect on the data is unknown. Failure to adequately manage confounders can create a fundamental flaw in the design of a study (Polit & Beck, 2008). Systemic differences between the control and intervention groups are likely to either over estimate or under estimate the effects of the intervention.

To summarise, the predominance of B&A studies in ED CCDSS research has warranted a detailed appraisal of this as a research method. Several authors discount the method as a means of contributing to the CCDSS evidence base as the risk of bias is unacceptably high (Liu & Wyatt, 2011; EPOC, 2013b). The challenges of conducting RCTs in ED setting make this relatively easy research method appealing. However due to the intrinsic risk of bias identified in these studies one can not draw any firm conclusions about the effectiveness of the CCDSSs under investigation. The next section in the literature review analyses the included studies that adopted an ITS design.

### **3.9 Interrupted time series that have assessed the use of CCDSSs in EDs**

Five studies have evaluated the implementation of CCDSSs in ED with an ITS design (Day et al., 1995; Schriger et al., 1997; Schriger et al., 2000; Buising et al., 2008; Gibbs et al., 2012). None of them evaluated a CCDSS for use at Triage. ITS studies collect data at multiple time points before and after the implementation of the intervention (Cochrane, n.d.). Collection of data at multiple points before the intervention reveals the underlying trend, which will have a naturally occurring variation. The analysis, which compares the data points after the intervention can take account of this underlying trend to enable the effect of the CCDSS to be shown (EPOC, 2013b). ITS studies, if conducted appropriately are deemed of sufficient quality to be included in EPOC reviews (EPOC, 2013b). EPOC (EPOC, 2013a, 2013b) stipulate that ITS studies must meet the following criteria to be included in their reviews:

- Secular trends must be analysed (a simple t-test pre and post intervention is insufficient)
- There must be a clearly defined point in time when the intervention was introduced
- There must be a least three time points where data is collected before and after the intervention

These elements are seen as being fundamental to reducing the risk of bias. In EPOC systematic reviews studies that meet these inclusion criteria are then

subject to critical appraisal using the following seven criteria to judge their risk of bias (EPOC, 2013a).

1. Was the intervention independent of other changes?
2. Was the shape of the intervention effect pre-specified?
3. Was the intervention unlikely to affect data collection?
4. Was knowledge of the allocated intervention adequately prevented during the study?
5. Were incomplete outcome data adequately addressed?
6. Was the study free from selective outcome reporting?
7. Was the study free from other risks of bias?

### *3.9.1 Critical appraisal of the ITS studies*

The study by Gibbs et al (2012) evaluated a CCDSS to improve the care of patients presenting with CAP. It used a ITS design over a 33 month period analysing the care of 1185 patients in total. Of the four key outcome measures there were statistically significant changes in three: blood cultures prior to antibiotics, antibiotics within six hours of arrival and appropriate antibiotic selection. The fourth measure, mean time to antibiotics decreased by one minute but this change was not significant. A brief conference abstract of the study has been published but no methodological information is available despite email contact with the authors. Therefore any rigorous critical appraisal of the method has not been possible.

Three of the ITS studies were generated from the same academic ED (Day et al., 1995; Schriger et al., 1997; Schriger et al., 2000). The UCLA ED developed an Emergency Department Expert Charting System (EDECS) in the 1980s. EDECS provides a complete EPR including investigations, treatment orders, prescriptions and discharge instructions for patients. Clinical guidelines function in the background and where relevant investigations or treatments are either: strongly recommended, optional or discouraged. Deviation from the suggested actions were always permitted. Clinical guidelines for acute low back pain (Day et al., 1995), health care worker exposure to body fluids (Schriger et al., 1997) and fever

in the under three year old (Schriger et al., 2000) have all been embedded into the system over a five year period and evaluated using ITS. All three studies state they have used an ITS method. The study of patients with acute low back pain was the first to evaluate EDECS (Day et al., 1995). It describes the design as a “prospective, time series comparison of control and test periods” (Day et al., 1995). However in terms of an ITS study its design is methodologically weak. There is no discussion of the time points over which the data was collected. In the “before” period a random sample of 103 patients were analysed (from a total of 206). In the “after” period 259 patients met the inclusion criteria and were included in the analysis. From these details it appears that the method is more consistent with an uncontrolled B&A study. In the “before” period data was manually abstracted from the hand written charts. There is no mention of a standardised abstraction sheet, training of the abstractors or any inter-rater reliability testing. There was no comparison of the before and after groups to assess if there were any fundamental differences that may account for any change in physician behaviour. No limitations of the study were discussed despite some fundamental risks of bias, namely: selection, performance and detection biases. Together with the issues of regression to the mean and the failure to consider any confounding variables the results of this study do not permit any firm conclusions to be drawn about the impact of EDECS on patient care or physician behaviour.

The remaining two ITS studies from UCLA ED analysed the effect of clinical guidance embedded into EDECS for health care workers exposed to body fluids (Schriger et al., 1997) and febrile children under 3yrs of age (Schriger et al., 2000). Both studies used the same method: an off, on, off design with intention to treat analysis (and with a second off phase). Outcomes measures were similar: quality of clinical documentation, provision of aftercare instructions, compliance with testing and treatment decisions and cost of care. Both studies showed significant increases in quality of documentation and issuing of aftercare instructions. Compliance with testing and treatment decisions only improved for patients with exposure to body fluids (Schriger et al., 1997). This off, on, off design is not a true

ITS study. The second “off” phase was when the intervention, the embedded clinical guideline, was removed. The aim was to assess if the outcomes measures returned to baseline as this final phase was regarded as a second control group. This method was slightly different to the first EDECS study by Day et al (1995) as it has a second “off” phase. Additionally there were attempts to manage some causes of bias.

In both these studies in the two “off” phases data was collected from the clinical record by trained abstractors. They were tested to ensure the error rate was <2% and there were periodic quality checks. No abstraction was needed for the “on” phases as this could be directly exported from EDECS. Both studies compared the characteristics of the three study groups (off, on, off) and the characteristics of the treating physicians. Regression to the mean whilst not mentioned may be less of an issue as the outcomes in the final phase of both studies returned to baseline. There was no consideration regarding confounders (experience of the physician), selection bias (similarity of the groups) and detection bias (training and assessment of abstractors). Data was not collected at regular intervals before and after the intervention and therefore there was no analysis of underlying secular trends. These are fundamental elements of ITS design as stipulated by EPOC (2013b, 2013c). It is difficult to draw any definite conclusions about the true effects of either guideline embedded into the EDECS. Interestingly the study of fever management did not show any changes in test ordering or appropriateness of care (Schriger et al., 2000). There are fundamental issues with the development of the fever guideline and lack of consensus regarding its appropriateness amongst the physicians using it. Undoubtedly this will have had an effect on compliance.

The final ITS study included in the literature review included a time series analysis as part of a B&A cohort study (Buisson et al., 2008). This study demonstrated the most rigorous ITS method when investigating the impact of a CCDSS on concordant antibiotic prescribing for CAP. The study took place over a 41-month period during which there were 3 distinct phases. Phase 1 was the baseline “pre-intervention” period, which lasted 12 months. After an 11 month gap phase 2

began, lasting 8 months and saw the introduction of an intervention to increase antibiotic concordant prescribing - academic detailing. Academic detailing is a process for face-to-face education aimed at improving prescribing (National Resource Centre for Academic Detailing, 2014). Finally after a gap of 6 months phase 3 began with the introduction of the CCDSS; lasting 5 months. A single trained research nurse collected data on every eligible patient during this time; an infectious disease physician checked five percent of these judgements.

Multivariate logistic regression was used to compare concordant prescribing during the three phases whilst adjusting for disease severity and the age of the patients. However there was no consideration given to the experience of the prescribing clinician as a possible confounder. Clinician exposure to the CCDSS was associated with higher odds of concordant prescribing (OR 2.03 [1.13-3.66]) after adjustment for patient age and disease severity. In general terms prescribing patterns improved over time, as one would expect. However the time series regression analysis in this study revealed that during the CCDSS phase the degree of concordant prescribing was higher than the expected underlying trend. With regard to the EPOC (2013b, 2013c) criteria for ITS studies this research addresses many of the criteria associated with reducing the risk of bias.

ITS studies, if properly designed appear to be an appropriate method for assessing the impact of a CCDSS intervention. However only one study using an ITS method for evaluating CCDSS in EDs considered the underlying secular trend (Busing et al., 2008). It is therefore difficult to draw any overall conclusions about the impact of CCDSS in ED and further studies using well designed ITS studies are required.

### **3.10 Other designs**

The final two studies in this literature review utilise a prospective observational design (Dong et al., 2005) and a retrospective comparative cohort design (Lim et al., 2012). The study by Dong et al (2005) is the only study to analyse the effectiveness of a CCDSS for the CTAS. In this study a convenience sample of 693 patients were triaged using the usual “memory-based” triage method by the

triage nurse that was on duty. Patients were then “re-triaged” by a blinded research nurse using the CTAS CCDSS. The results of both triage decisions were then compared using kappa statistics. Agreement was poor ( $\kappa = 0.202$ ). An expert panel assessed 100 triage records and there was more agreement between the experts and the CCDSS than the triage nurses. This is an important study as it is the only one that specifically evaluated a CCDSS for emergency triage. The results suggest that a CTAS CCDSS supports better triage decisions than the usual triage method when compared to an expert panel.

However there are some weaknesses in the conduct of the study. Firstly this study did not consider any confounders e.g. triage nurse experience. The study itself even introduced confounders through its design. The research triage nurse using the CTAS CCDSS triaged the same patients some time after their initial triage and when they had already been directed to a clinical area in the ED for their subsequent care e.g. majors, resuscitation, minors. This process eliminated the time pressure that triage nurses face when having to make rapid decisions often in an environment fraught with interruptions (Edwards, 2003). Secondly, the research nurse was triaging patients in the areas where their care was being delivered. There is no mention of the time lapse between the two triage assessments, how this may have subconsciously influenced any decision or if care delivered altered the patient’s condition. Despite the blinding of the research nurse to the first triage decision the effect of these confounders on decision-making is unknown. The creation of detection bias does not enable any firm conclusions to be drawn regarding the results.

A comparative cohort study by (Lim et al., 2012) evaluated the impact of the use of an electronic clinical practice guideline (eCPG) on the management of patients with neutropenic sepsis. Outcome data was retrospectively extracted from clinical records across four EDs in Canada over a 3 year period. Overall the use of the eCPG was low, 37.8% overall, although in the intervention ED it was 57%. The intervention ED was designated as such as it was the largest cancer centre in the province with wide use of the eCPG. The 3 control EDs did have access to the eCPG; it was used in 19% of patients in one of these EDs and there was no record

of its use in the other two. As the designated cancer hospital the intervention ED treated 57% more patients with neutropenic sepsis (n=128) than the three control EDs combined (n=73). When the eCPG was used there was a statistically significant improvement in ECG recording and collection of blood cultures. There were statistically significant reductions in triage to doctor assessment time and triage to first antibiotic. Again this study like many others in this literature review failed to address confounding variables. The most likely confounder to affect the care of patients in the intervention hospital is experience of managing patients with neutropenic sepsis. Also, even when the eCPG was not used, its prior use by that treating physician may have altered the type and timeliness of care.

### **3.11 Summary**

This literature review has identified and critically appraised 23 studies that have evaluated the impact of CCDSSs on care in EDs (only one of these focussed on Triage). The results of 13 of these studies identified a statistically significant impact on clinical care with the use of a CCDSS (Schriger et al., 1997; Goergen et al., 2006; Buising et al., 2008; Jadav et al., 2009; Kwok et al., 2009; Roy et al., 2009; Drescher et al., 2011; Gibbs et al., 2012; Lim et al., 2012; Raja et al., 2012; Bond et al., 2013; Britton et al., 2013; Jones, B. et al., 2013). They all demonstrated an increase in guideline adherence that ensured patients received the correct treatment, for example the appropriate antibiotic or an appropriate radiological investigation. Some studies also demonstrated that for patients with critical illness the speed with which they received treatment improved significantly, for example patients with neutropenic sepsis (Lim, C., 2012).

Two studies showed no benefit after the introduction of the CCDSS (Asaro et al., 2006; Dexheimer et al., 2013). The remaining 8 studies showed some small improvements in care, mainly concerned with documentation (Day et al., 1995; Schriger et al., 2000; Dong et al., 2005; Roukema et al., 2008; Melnick et al., 2010; Carman et al., 2011; Nelson, J et al., 2011).

Whilst more than half of the included studies show favourable results, an analysis of the methodological quality revealed a high risk of bias in all but six studies



(Busing et al., 2008; Kwok et al., 2009; Roy et al., 2009; Melnick et al., 2010; Raja et al., 2012; Jones, B. et al., 2013). Only one RCT adequately addressed performance and detection bias (Roy et al., 2009). Only one of the five ITS studies considered the underlying secular trend within the analysis (Busing et al., 2008). And of the B&A studies (themselves methodologically questionable due to inherent bias) less than one third considered and statistically adjusted for confounding variables (Kwok et al., 2009; Melnick et al., 2010; Raja et al., 2012; Jones et al., 2013).

To date there has been no other published reviews that have specifically considered the effectiveness of CCDSSs in ED's. This review has revealed a slowly increasing body of literature but predominately with a known weak design - the uncontrolled B&A study. Whilst relatively easy to implement in a clinical environment fraught with challenges, the threats to internal validity do not permit any confident conclusions to be drawn about any casual relationships.

In order to help focus the research in this thesis, the selection of resources for this review has been restricted to studies that have been conducted in EDs. Other studies that may offer insights into more general CCDSS use, or the use of other forms of health IT in EDs have been considered but not included in the formal review itself. For example, there is research into the general use of CCDSSs in nursing and their effects on patient outcomes (Dowding, Turley , & Garrido, 2012); a recent systematic review has appraised CPOE studies in EDs (Georgiou et al., 2013); and there is a also a growing body of literature evaluating the use of CCDSS in telephone consultations (Crouch & Dale, 1997; Dale et al., 2003; Campbell, J. et al., 2013).

The results of the higher quality studies within this literature review are encouraging as the challenges that ED clinicians face in delivering consistently high quality are ever increasing. Further high quality evidence of effectiveness is required to enable the role of CCDSSs in enhancing quality and safety in EDs to be more fully understood.

This literature review has informed the appropriate selection of a methods to evaluate the CCDSSs in this study. The research methods chapter that follows will describe the study that was undertaken to evaluate a CCDSS in an ED. The rationale for the research, which based on the current clinical context and current gaps in the evidence will be described in detail together with the research methods employed.

## CHAPTER 4: RESEARCH METHODS

### 4.1 Introduction

The following chapter describes the research design and methods used to investigate the impact of an emergency triage CCDSS (eTriage) on quality and safety. The research question will be revisited together with the primary and secondary outcome measures. It is from the research question that the research perspective underpinning the study developed. The quasi-experimental design used was selected following analysis of several different methods identified in the literature review. The design of the study, its setting, sampling approach, data collection methods and internal validity will be explained in detail. The approach to data analysis is explained and justified. Finally, ethical issues and research governance during the study are outlined.

### 4.2 Research Question

As given in the introduction, the research question is:

*Does the introduction of a computerised clinical decision-support system eTriage improve the quality of triage decisions and safety within the ED?*

#### 4.2.1 Outcome measures

The primary outcome measure was concerned with the safety and quality of the triage decision-making process. This was judged by assessing the following:

- a. The accuracy of the triage prioritisation process
- b. The assessment of pain
- c. The appropriate management of any pain identified at triage.

The secondary outcome measure was concerned with patient safety and assessed the management of patients that presented with possible neutropenic sepsis. Appropriate management was judged by assessing the following:

- a. Triage priority allocated as “very urgent”

b. Full blood count taken within one hour

c. Timeliness of antibiotics.

#### **4.3 Rationale for this research**

This research was undertaken to test the assumption that eTriage provides consistently safer and higher quality triage decisions when compared to the traditional triage method. At the beginning of eTriage's development a scoping review of a small number of studies revealed a positive impact on clinical care when CCDSS were used (Goergen et al., 2006; Liu et al., 2006; Roukema et al., 2008). However, it was not until the comprehensive literature review and critical appraisal of studies was undertaken that equally important reasons for this doctoral research were identified:

- There have been no published reviews that have assessed the value of CCDSSs in EDs
- The review of the ED CCDSS literature within this study has revealed a significant number of studies of questionable quality
- Only one relevant study has been identified that has been conducted in the NHS.
- There are unique challenges currently facing UK NHS EDs which warrant specific investigation

The majority of published studies cite common reasons for the development of CCDSSs in ED. These challenges relate to: clinical guideline adherence (Busing et al., 2008), environmental challenges, namely overcrowding (Bond et al., 2013) and the increasingly complexity of patients and their management (Gibbs et al., 2012). The critical nature of some conditions e.g. sepsis and improved mortality and morbidity with timely treatment are also cited by several studies (Nelson, J et al., 2011; Bond et al., 2013). In addition to these universal reasons for ED CCDSS development at the time of this study the NHS had additional challenges. NHS EDs struggled to meet their national performance targets in 2013 and chronic staffing

shortages led to additional financial support from the Department of Health (Health Select Committee, 2013a). The inability to recruit experienced ED clinicians (O'Dowd, 2013), an increasingly inexperienced junior clinical workforce (Armstrong et al., 2008) and the economic climate at the time created a situation where innovative means of supporting clinical decision-making required urgent investigation (NHS Institute for Innovation and Improvement, n.d.). ED staff and patients will undoubtedly benefit from the use of CCDSSs that demonstrate positive improvements to care process and/or patient outcomes. Whilst positive results from this study were clearly desirable the overriding aim of any CCDSS research is to identify if systems are of benefit to clinicians and patients. In the same way that the effects of drugs or surgical techniques are evaluated, CCDSS research should be rigorously undertaken before systems are disseminated (Haynes & Wilczynski, 2010). It is vital that CCDSSs are evaluated to demonstrate evidence of benefit versus harm as well as cost-effectiveness (Shcherbatykh et al., 2008). It is critical to understand what CCDSSs can and cannot contribute to quality and safety in emergency care and this is what this research set out to determine. This research study and the research method that was selected add to the small body of higher quality studies and deepen our understanding of the role of CCDSS in ED with a degree of confidence.

#### **4.4 Research perspective**

The expression “research perspective” is used in this chapter as an umbrella term to describe and analyse the overall orientation of this research. A positivist approach has been selected as the most appropriate method by which to answer the research question. Healthcare research is increasingly pragmatic using the most appropriate means to answer research questions (Broom & Willis, 2007; Saks & Allsop, 2007). This study sought to understand the contribution of eTriage and was concerned with understanding if it made a difference: yes or no. A quantitative method was required to answer this question with clarity and confidence in an objective and rigorous way (Punch, 2006). This research set out to measure the difference in clinical decision-making before and after the introduction of a CCDSS. Measuring this difference quantitatively enabled the

research question to be answered and generated new knowledge about the clinical impact of CCDSSs in EDs. The results of this study will add to the ED CCDSS evidence base. In particular its robust design will further contribute to the debate regarding suitable approaches to investigate CCDSS in complex clinical settings. Generating original knowledge that will complement, contradict or add another dimension to what is already known, is the whole premise of social science research (Taylor & Hicks, 2009).

This research investigated the decisions that clinicians make when managing patients using one of two triage systems; more specifically, whether they make an accurate decision. It was not concerned with how those decisions were made or the cognitive processes that were used to arrive at one decision over a number of others. While both these issues are of value, this study evaluated the impact of CCDSS on the accuracy of triage decisions and tested the assumption that it can consistently improve them. A quantitative method was the most appropriate way to give a definitive answer to the research question. When considering methodological approaches it is important to consider whether the approach used, quantitative or qualitative, is based upon the underpinning philosophical beliefs of the researcher or has been selected from a pragmatic standpoint (Broom & Willis, 2007). A pragmatic stance was taken for this research that was not philosophically driven. There would be additional value in understanding triage decisions that a qualitative study could unearth. This may also lead to the development of strategies that could improve triage accuracy. However this research did not seek to explore this perspective. Punch (2006) asserts that the issues of perspective, paradigm, epistemology, ontology and philosophical position are less important in some areas of social science research than others. Adopting a pragmatic standpoint enabled this research to begin and end based on the proposition that

“questions need answers and problems need solutions”

Punch (2006) p32

eTriage was developed because of the inconsistency in clinical decision-making and the actual and potential risk that this posed to patients; *the problem that needed a solution*. This research was undertaken to test the assumption that eTriage consistently improved clinical decision-making; *the question that needed answering*. Research that is approached from a pragmatic and practical standpoint as opposed to a philosophical one must still consider how the overall research perspective will influence the research strategy and design of the study. There will be inherent positivist influences when adhering to a quantitative research design and the maintenance of rigour. These issues will be addressed in the rest of this chapter and throughout the thesis. Chapter 7 provides a reflective account on the role of the practitioner researcher during this research journey. Career-long professional influences are considered and their impact on the underpinning epistemological standpoint of the researcher.

## **4.5 Research strategy**

eTriage had already been introduced as an intervention to support increased demand and mitigate against threats to quality and safety that increased activity and inexperience may produce. A quantitative method had already been identified as the most appropriate means by which to answer the research question. Once a quantitative approach was deemed the most suitable to answer the research question the search for a robust design began. A quasi-experimental design was selected after careful consideration of alternative quantitative designs identified by EPOC (2013b), namely a randomised controlled trial (RCT), a non-randomised controlled trial (NRCT) and a controlled before and after study (CBA).

### *4.5.1 Randomised controlled trials*

RCTs are often viewed as the gold standard design for studies investigating cause and effect (Polit & Beck, 2008). They are often not possible in biomedical informatics research due to the challenges of randomising and blinding participants and researchers (Friedman & Wyatt, 2010). The comprehensive series of six systematic reviews on CCDSSs published by Hemens et al (2011), Nieuwlaat et al (2011), Roshanov et al (2011a), Roshanov et al (2011b), Sahota et

al (2011) and Souza et al (2011) chose to include only RCTs (Haynes & Wilczynski, 2010). Whilst RCTs have been used in the study of CCDSSs in acute care (Sahota et al., 2011) only 4/36 (11%) studies included in the acute care systematic review were undertaken in an ED (Gonzalez, Vanderheyden, Ornato, & Comstock, 1989; Wyatt, J, 1989; Roukema et al., 2008; Terrell et al., 2009). Two provided guidance on drug dosing in a specific clinical situations; asthma and in older people respectively (Gonzalez et al., 1989; Terrell et al., 2009). The other two studies suggested actions in single discrete clinical situations; chest pain (Wyatt, J, 1989) & clinical investigations for children at high risk of serious bacterial infection (Roukema et al., 2008).

Within the more recent literature review for this thesis a further two RCTs were identified (Roy et al., 2009; Dexheimer et al., 2013). The studies by Wyatt (1989), Terrell et al (2009) and Gonzalez et al (1989) did not meet the inclusion criteria for the literature review in this thesis. Of the remaining three RCTs that were critically appraised, two had methodological weaknesses (Roukema et al., 2008; Dexheimer et al., 2013) and the cluster RCT by Roy et al (2009) whilst methodologically stronger was a very significant undertaking as it took place in 20 EDs across France. The maintenance of the internal validity of an RCT in the ED setting to evaluate the impact of CCDSSs is very challenging. Both the studies by Roukema et al (2008) and (Dexheimer et al., 2013) were not able to adequately control for the contamination that resulted from the clinician not being blinded to which arm of the trial the patient was in i.e. control or intervention.

For this study it was not be practical or feasible to randomise ED patients to a control group (usual triage) and an intervention group (eTriage). One of the strengths of this research is that it was conducted in clinical practice and evaluated the impact of the CCDSS in current use. Running two parallel triage systems (usual triage and eTriage) and then randomising patients to one or the other would not be workable in a busy ED. There would need to be two triage points: usual triage and eTriage. The patient would attend one or the other, depending on which they were randomised to. Alternatively a single triage nurse could alternate between systems depending on which one the patient was



randomised to. In both these scenarios blinding would be impossible and performance bias as well as the risk of contamination would have an unknown effect on the results (EPOC, 2013a).

An alternative approach could have been a two-centre study. Another ED that used the MTS could have been selected as the control. Randomised triage records could have been analysed from both departments. It would have proven more difficult to retrieve data regarding patients who presented with neutropenia from another hospital. Most EDs have unique processes for managing patient flow and acuity due to differing departmental geography and staffing levels. Some efforts were made to establish if a local department had similar characteristics to the ED in this study to reduce the impact of potential confounding factors. For example: similar geographical layout, cubicle space, staffing levels, triage training and level of triage nurses' experience. None were viewed by the researcher as a suitable match.

Of equal importance to this study was the secondary outcome measure, which assessed the impact of eTriage on the management of patients with neutropenic sepsis. Comparing processes for that patient group in another ED would not be appropriate either for the reasons outlined above. It is also important to highlight that eTriage was a planned development within the ED, despite the research that was subsequently undertaken. Once a new process or system has been introduced, the use of an appropriate experimental design to evaluate it is more limited (Siriwardena, 2007).

Once the feasibility of undertaking a RCT was explored and rejected an assessment of other appropriate methods was necessary. A research method was required that could be administered in a busy ED with minimal disruption but that was robust enough to give an acceptable degree of confidence in its results. EPOC (2013b) recognise that RCTs are often not appropriate methods for research into interventions to improve health care delivery. The other study designs that are viewed as appropriate for inclusion in an EPOC systematic review, if they are conducted robustly are: NRCTs, CBA studies and ITS design (EPOC, 2013b). It is

with these criteria in mind that NRCTs, CBA studies and ITS design were also considered.

#### *4.5.2 Non-randomised designs*

When an intervention has already been introduced, as in the case of eTriage non-randomised methods (NRCT) or quasi-experimental designs (CBA studies, ITS design) are often an appropriate research option (Siriwardena, 2007). A NRCT has two study groups one exposed to the intervention, while the other acts as the control. The participants are allocated to either group by methods which are arbitrary (Cochrane Childhood Cancer Group, n.d.). In a NRCT the participants are opportunistically allocated to either the control or intervention group. Lack of randomisation is seen as a significant flaw in a trial's design as it introduces potential bias (Higgins & Green, 2011). There may be naturally occurring differences between the groups e.g. age, gender, severity of illness and the process of non-random allocation itself creates selection bias (Higgins & Green, 2011). Matching subjects with similar characteristics can be undertaken to reduce bias. However, in a comprehensive study which compared the results of studies from randomised and non-randomised trials on the same intervention, differences were found (Deeks et al., 2003). There was an overall conclusion that an evidence-base may need re-examining if established through non-randomised designs (Deeks et al., 2003). In some clinical settings a NRCT may be more feasible than an RCT, however the impracticalities of running two different triage systems simultaneously regardless of whether the patients are randomised or not remain the same. Whilst it has been established that an RCT is not appropriate method for practical reasons, a NRCT was discounted as well due to the same practical reasons as well as its inherent bias.

#### *4.5.3 Before and after studies*

A CBA study is identified by EPOC (2013b) as an appropriate method for inclusion in their systematic reviews. However, in an ED setting the concurrent identification of an intervention and a control group that have the primary and secondary outcomes measured before and after the introduction of eTriage is

impossible. Within the literature review for this thesis no CBA studies were identified. ED patients are transient; the identification of a concurrent control group is not feasible. For this reason alone the use of a CBA study was dismissed.

Although simpler, a B&A study is not viewed as suitable means of assessing the impact of an intervention to improve practice (EPOC, 2013b). Despite this they are the most predominant method used in CCDSS research (Liu & Wyatt, 2011). They are also the most common method identified in the literature review within this thesis. Thirteen B&A studies were included and significant threats to internal validity were identified by the use of this method (Asaro et al., 2006; Goergen et al., 2006; Jadav et al., 2009; Kwok et al., 2009; Niemi et al., 2009; Melnick et al., 2010; Carman et al., 2011; Drescher et al., 2011; Nelson, J et al., 2011; Raja et al., 2012; Bond et al., 2013; Britton et al., 2013; Jones, B. et al., 2013).

EPOC (2013b) dismiss the use of B&A studies due to their inherent risk of bias. In a B&A study the outcomes of interest are measured “before” the introduction of the CCDSS and “after”. Any changes are assumed to be due to the effects of the CCDSS (Siriwardena, 2007). However, one-off measurements before and after an intervention do not take into account natural changes that occur, regression to the mean or the influence of other external factors such as newly trained triage nurses (Polit & Beck 2008). There are always changes to behaviours, performance and adherence to guidelines for example, that alter over time. In a B&A study the underlying trend that would naturally occur is not evident and spurious results and the phenomenon of regression to the mean can arise depending on when the measurements are taken. See Figures 4.1 & 4.2 below for diagrammatic representation of these issues.

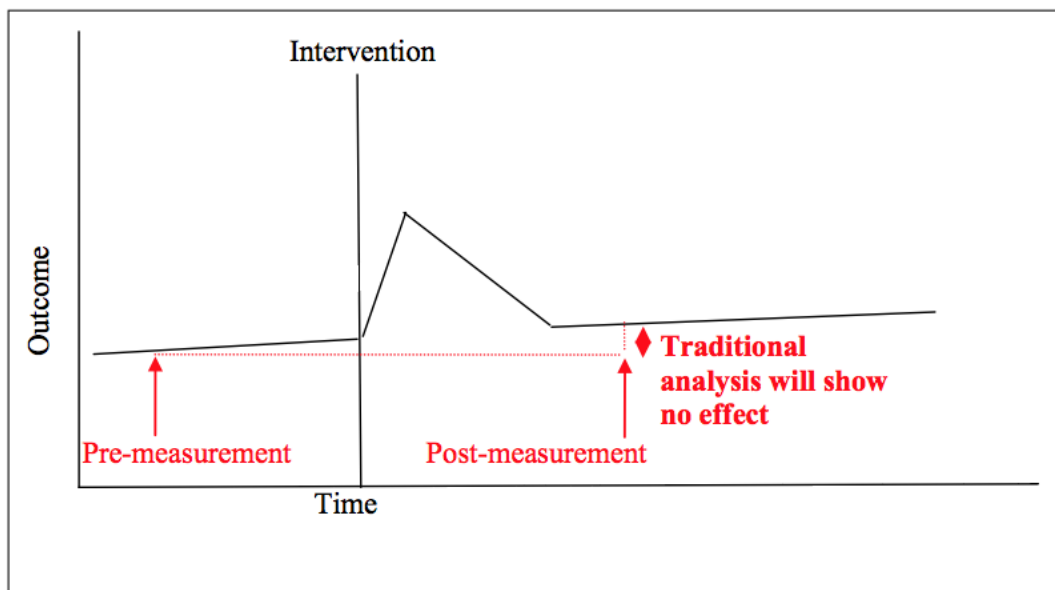


Figure 4.1. Before and after study. On-off measurements will not show the effect immediately post intervention adapted from Bender (n.d)

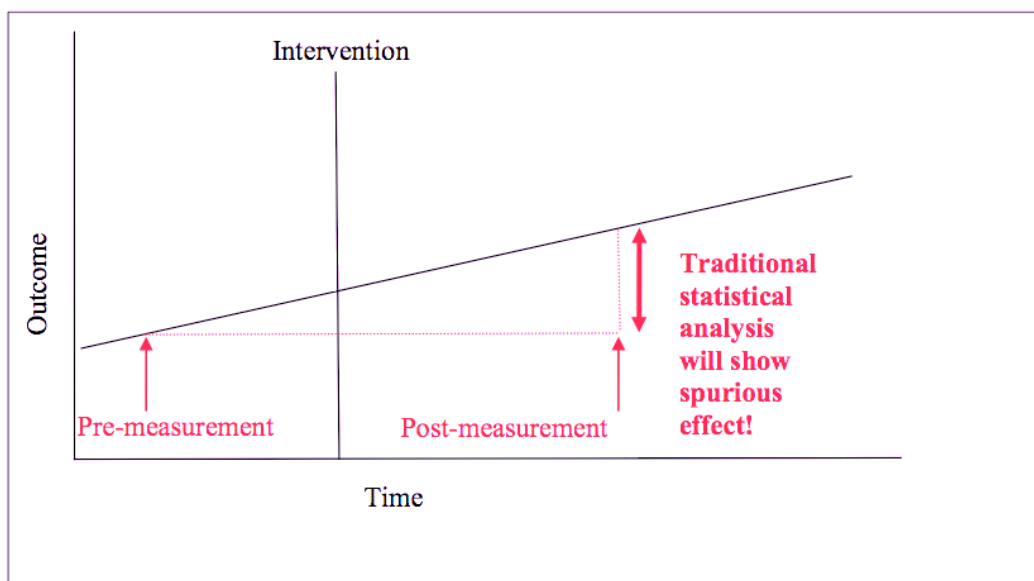


Figure 4.2. Before and after study. One-off measurements will not show that the intervention has made no difference if the underlying trend is not visible adapted from Bender (n.d)

A simple B&A study taking a single set of measurements before and after the introduction of eTriage was rejected. Whilst appealing to many CCDSS researchers due to its relative ease there are several significant threats to internal validity that result from; selection bias, performance bias, detection bias, attrition bias,

reporting bias and regression to the mean (Robson et al., 2001; Higgins et al., 2011; Higgins & Green, 2011). The next sections will describe in more detail the research design adopted.

#### *4.5.4 Interrupted time series designs*

ITS design is a quasi-experimental approach that has been used in CCDSS research. It is particularly well-suited to assessing the effects of the introduction of an intervention (Polit & Beck, 2008). ITS design has been used to assess the impact of: the introduction of new guidelines (Sheldon et al., 2004), health education interventions (Michielutte, Shelton B., Paskett, Tatum, & Velez, 2000), an electronic health record on nursing activities (Dowding et al., 2012), a CCDSS for antibiotic prescribing (Busing et al., 2008) and changes to legislation (Hawton et al., 2009). In an ITS study, repeated measurements are taken before and after the introduction of an intervention (Belcher, 2001). Measurements can be taken from the whole population or a sample if the population is large (Polit & Beck, 2008).

The strength of a ITS design, over-and-above a B&A study is that it removes some of the difficulties associated with invalid results from one-off measurements taken at a single point before and a single point after. Collecting data at intervals over a longer period of time before and after the introduction of an intervention will reveal the underlying secular trend (Biglan, Ary, & Wagenaar, 2000). This allows for stronger conclusions to be drawn about the actual effect of the intervention over and above what would have happened regardless of its introduction (Siriwardena, 2007; Flodgren & Oddgard-Jensen, 2013). The main source of bias in an ITS design remains the external effects on the change over time. However this is mitigated to a significant degree by the collection of data at multiple time points and the fact that pre-intervention data acts as the control (Polit & Beck, 2008). An ITS design was an appropriate method for this research for several other reasons. It is eminently suited to the retrospective analysis of data (England, 2005). As this research had no funding associated with it, a cost-effective method was necessary. ITS design is an emerging method in CCDSS

research; five studies having been identified in the literature review (Day et al., 1995; Schriger et al., 1997; Schriger et al., 2000; Busing et al., 2008; Gibbs et al., 2012). Although the quality of all but one of these studies was relatively poor (Busing et al., 2008), there was an opportunity with this research to add to the small body of higher quality research using an ITS design. Finally an ITS study can identify trends that an RCT is unable to isolate e.g. the immediacy of changes, the timing of the changes and the sustainability of the changes over time. It is of particular interest in this study to determine if any immediate improvement due to the launch of a novel system is maintained in the long term.

Taking all these features and limitations of the various study designs into consideration, an ITS design was selected as the most suitable approach for this research. The preliminary statistical analysis described later in the chapter and reported in chapter 5 did compare the pre and post eTriage groups (in a similar way to a B&A study). If large effects are demonstrated this can provide convincing evidence of the effect of an intervention (Brown & Lilford, 2008) However, to improve the quality of the study and reduce bias time series analysis was undertaken to evaluate changes over time based on the methods used by Busing et al., (2008). ITS design cannot determine cause and effect in the same way that a true experiment can (Sheldon et al., 2004). However, it can establish if the intervention was associated with a sustainable statistically significant change.

#### **4.6 Research design**

This next section will outline the complete design of the study and describe the setting, the samples used for the ITS and the data collection methods. The internal validity and the methods used to address confounding variables are described. The approach to and results of the inter-rater reliability testing will be explained. Finally the data analysis using SPSS (20.0) will be described and justified.

## 4.7 Setting



This research evaluated the triage decisions made in a district general hospital emergency department in the north of England. The department had used the MTS as its triage method since 1998. The pre eTriage data collection period ran from April 2009-January 2010; the post eTriage data collection period ran from April 2011-January 2012. The department covered a large urban and rural catchment area and saw a 2.6% increase in attendances during 2009-2011. Interestingly there was a significant increase in annual attendances in 2012 by a further 5.5%. The overall increase in attendances between 2009-2012 was 8.2%; 83,266 attendances in 2009 and 90,081 in 2012 (HSCIC, n.d.) The ED was situated in a large town with a population of approximately 300,000. Access to emergency or urgent health care for residents was via their own GP, an out-of-hours provider when their GP surgery was closed or by attending the ED. During the study period, a walk-in centre opened in October 2009, providing an alternative for patients with minor complaints, but closed in September 2010 as ED attendances continued to rise during the time rather than decline as was originally hoped. Most large towns and cities have alternatives to ED in the form of walk-in centres and minor injury units. They are either co-located with EDs or on a separate site, usually in the town/city centre. The provision of out-of-hours urgent and emergency care is somewhat unique in this locality as there were no alternatives as outlined above.

It is commonplace in most UK EDs for patients to arrive by one of two 'doors'. Patients that are brought in by ambulance arrive via an ambulance entrance. Patients that "walk-in" are those that have travelled by any other means and they have a separate entrance. In the case of this ED the walk-in entrance led into a waiting room with a large reception desk. All newly arrived patients were registered as an attendance into the hospital's patient administration system (PAS). Once registered, patients waited for assessment by a triage nurse. There were two separate triage points depending on the patients' mode of arrival: ambulance triage and "walk-in" triage. Patients who arrived by ambulance were triaged in a different physical location from those who walked-in. A small subset

of patients attending this ED did not undergo a triage assessment as they were assessed by a clinician on or shortly after arrival. This group of patients broadly fell into two categories. For a small number of critically ill or injured patients the ED receives a “stand-by” telephone call from the ambulance service. A clinical team meets the patient as they arrive and treatment begins immediately, therefore negating the need to for a triage assessment. During periods of reduced activity, usually between 05:00-09:00hrs clinicians might be ready to assess patients at they arrive - again negating the need for triage. The researcher for this study is a Senior Nurse working in the ED with a joint clinical and service/staff development role. The ED staff were not aware that the research was taking place.

Several organisational changes took place in the ED during the data collection periods, 2009-2012. In December 2010 the Department of Health introduced new A&E clinical quality indicators for launch in April 2011 (DH, 2010a). This set of measures replaced the previous single measure of performance, the four-hour standard. Indicator 6 was concerned with the initial assessment (triage) of patients arriving by ambulance. It set a standard that 95% of patients arriving by ambulance should receive an assessment, which includes a brief history, pain and early warning scores within 15 minutes of arrival. In order to meet this new standard nursing staff were deployed differently. To ensure that all patients who arrived by ambulance received a prompt assessment a Registered Nurse was designated to ‘Ambulance Triage’. An area with two cubicles to accommodate ambulance stretchers was created. Prior to this change the shift leader (a senior clinical nurse) triaged all the patients arriving by ambulance as well as being responsible for the overall management of the ED. This change coincided with the post-eTriage data collection from April 2011. Secondly, in November 2011 a co-located children’s ED opened. From this date all children received their triage assessment in the children’s ED by Registered Children’s Nurses. This change was in place for the final data collection point of January 2012. See Table 4.1 for a timeline of these operational changes.



Table 4.1 Timeline illustrating operational changes within the ED during the study period				
eTriage	Pre eTriage data collection period		Post eTriage data collection period	
Time periods	April 2009	Jan 2010	April 2011	Jan 2012
				
Triage processes and operational changes	<b>Patients arriving by ambulance assessed by Nurse-in-Charge (senior nurse).</b> <b>Walk-in patients assessed by Registered Nurse (RN) triage nurse in one of two triage cubicles situated in the ED waiting room</b>		<b>April 2011</b> <b>Designated ambulance RN triage nurse</b> <b>Adult “walk-in” triage now in one cubicle in ED waiting room</b>	<b>November 2011</b> <b>All children now triaged in children’s ED by RN (Child)</b>

Additionally from 20<sup>th</sup> December 2012 until 27<sup>th</sup> March a project ran in the ED where certain patients were referred directly to see a GP based in the ED; these patients bypassed the ED triage system. This 13-week project did not coincide with any of the data collections periods.

#### 4.8 Sample

There were two separate data sets from which data was extracted and then analysed; these will be described in turn. To evaluate the ability of eTriage to improve decision-making at triage a sample of triage records was required. Using a random sample in quantitative research strengthens a study’s ability to make generalisations across the wider population (Davis & Scott, 2007). In ITS design it not usual to obtain a random sample as whole populations are often studied (Belcher, 2001). Hawton et al (2009) assessed the effects of the withdrawal of the analgesic co-proxamol in 2007 on the number of co-proxamol drug poisoning

deaths and prescriptions for the drug. They used national data covering England and Wales and analysed the death rate before and after 2007 using ITS design. In this example it can be relatively easy to analyse large sets of data when it has already been collected. With regard to the study within this thesis it would not have been possible to extract and code data from every triage record before and after the implementation of eTriage as this would equate to >240,000 records.

Statistical advice was sought regarding an appropriate sample size to enable statistically significant inferences to be drawn about the ability of eTriage to improve quality and safety. A power calculation with a level of significance set at 0.05, with a power of 80% identified that 100 records per sample month would be adequate. This sample enabled a reasonably robust regression analysis model to be constructed. The regression analysis assessed the effect of the intervention after adjusting for confounding variables and exposed the underlying decision-making trend.

A random sample of 100 triage records was taken every third month for a year prior to the launch of eTriage (2009-2010). One year post implementation a further random sample of 100 triage records was taken every third month for another year (2011-2012). A gap of one year between the data collection points enabled staff to become used to the CCDSS and any technological problems to be resolved. This ensured that data was collected on a stable CCDSS that staff were familiar with. See Table 4.2 for a diagrammatic representation of the ITS data collection points.

Table 4.2 Time series design

Data collection points	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Time intervals	<b>April 2009</b>	<b>July 2009</b>	<b>October 2009</b>	<b>January 2010</b>
Intervention	<b>12<sup>th</sup> April 2010</b>			
Date collection points	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
Time intervals	<b>April 2011</b>	<b>July 2011</b>	<b>October 2011</b>	<b>January 2011</b>

Points 1-4 represent 3 month intervals over a one year prior to the introduction of eTriage. Points 5-8 represent 3 months intervals over one year, one year following the introduction of eTriage.

The total sample size was 800; 400 records taken prior to the implementation of eTriage and 400 records afterwards. The random sample was obtained by utilising the unique identifier (A&E number) that was routinely allocated by PAS on each patient's attendance. At the beginning of every calendar year consecutive A&E numbers were allocated. For example if a patient registered at 12 midnight on 1/1/2013 the A&E number would be 13/00001, the next patient that registered would be allocated 13/00002 and so on. For each of the ITS study months the range of consecutive A&E numbers were identified to include all the patients that registered from 12 midnight on the 1<sup>st</sup> of the month to 23:59hrs on the last day of the month. This was repeated for all 8 of the study months. This generated a range of approximately 7,000 A&E numbers for each study month.

A random sample of 120 records, denoted by the A&E number were obtained for each month. The random sample selections were conducted in nQuery Adviser 7.0 using computer generated random selection algorithms. Based on advice from a statistician a decision was made to identify 120 random records. This enabled those records of patients who did not undergo a triage assessment to be excluded, still ensuring that there would be 100 randomised records each month to extract data from. There were no records excluded from the sample. For example adults and children were included as well as patients presenting with physical or mental health problems. The design of this study also ensured that the basic EPOC (2013b) criteria for ITS studies deemed suitable for inclusion in their reviews was met:

- There is a clearly defined time point when the intervention started
- There is the collection of data from at least three data points before and after the intervention

To evaluate the ability of eTriage to improve the safety of patients presenting with possible neutropenic sepsis the care of all patients that presented during the two 12 month study periods was reviewed (1/4/2009-31/3/2010 and 1/4/2011-31/3/2012). A decision was made to assess the whole neutropenic population that attended ED. National estimates suggested that approximately 3 patients per

month are admitted to district general hospitals with confirmed neutropenic sepsis (National Institute for Health Care Excellence, 2012). Patients with confirmed neutropenia (neutrophil count  $<1.0$ ) who had attended the ED would be identified from the hospital's haematology database.

#### **4.9 Data collection**

Data was collected by retrospective case note review to assess the accuracy of triage decisions and specific judgements were made regarding the following:

- Was an appropriate triage chart selected to assess the patient (see Appendix 13)? In some cases more than one chart may be appropriate for example head injury or falls would be acceptable for a patient that fell and hit their head. In cases like this either chart would be deemed appropriate
- Was a correct discriminator selected? Again in some patient presentations more than one discriminator would be appropriate. However the discriminator at the higher triage priority category should be selected. For example a discriminator in the very urgent priority category should be selected above one in the urgent category.
- Was the patient allocated to the correct clinical priority? Following the selection of the discriminator the triage nurse had to allocate the patient to the corresponding priority category

Two further areas of ED care were selected for measurement as they were deemed by the researcher to be appropriate markers for quality and safety, they were: pain assessment and management and the initial management of patients with potential neutropenic sepsis. The rationale for their selection was identified in Chapter 2 and will be further expanded here before the strategies for data collection are described

##### *4.9.1 Pain assessment*

A very commonplace challenge that faces clinicians when dealing with the majority of patients that attend ED is adequate pain management. Seventy eight

percent of patients that attend ED have a painful element to their presenting problem (Body & Foex, 2012). There are clear national standards for the assessment and management of pain (CEM, 2010b, 2010c). However, despite these guidelines national (CEM, 2010a) and local (Levy, personal correspondence, 2012) audit evidence has identified that pain management could be improved.

Despite MTS having pain assessment as a core function it is still done poorly (van der Wulp et al., 2011). Even when there is routine pain scoring at triage this does not translate to patients receiving analgesia (Jadav et al., 2009). Patients with low acuity problems experience delays with pain management as well as those with moderate to severe pain (Lee, G. et al., 2008; CEM, 2010a). Adequate pain management in ED appears to be an impossible aspiration and much of the literature identifies deficiencies in assessment, management or both (Teanby, 2003; Brockopp et al., 2004; Hwang, Harris, Morrison, & Richardson, 2006; Todd et al., 2007; Ducharme et al., 2008). However, patients view pain management at triage as very important and when managed properly it improves their overall satisfaction (Graham, J., 2002; Bhakta & Marco, 2014). There are huge opportunities with CCDSSs in the ED to have a significant positive impact on the quality of care for the large number of patients in pain. Incorporating the assessment and appropriate management of pain into eTriage was a means of addressing the shortfalls in care.

Data was collected to identify firstly if pain was assessed using a score and then secondly if analgesia was given that was appropriate to the patient's pain score. See Appendices 8 & 9 for the CEM pain management guidelines that were part the ED pain management policy at the time. These were used to assess the appropriateness of analgesia provision in adults and children (CEM 2010b, 2010c). Pain scoring and appropriate analgesia at Triage formed part of the primary outcome measure for this study together with the accuracy of the triage prioritisation as already discussed

#### *4.9.2 Neutropenic sepsis*

Neutropenic sepsis is most commonly seen in acute clinical practice as a consequence of chemotherapy. Over the last decade increasing numbers of patients are receiving chemotherapy at their local hospital, away from tertiary cancer centres (National Institute for Health Care Excellence, 2012). The risk inherent with this is that non-specialists have to identify and appropriately treat a new clinical emergency not previously encountered. Neutropenic sepsis is potentially fatal and mortality rates have been reported as high as 21% in adults (Herbst et al., 2009).

As identified in Chapter 2 an NCEPOD report into deaths within 30 days of chemotherapy identified significant shortfalls in initial care and assessment (Mort et al., 2008). Local guidelines immediately available in ED are seen as a key organisational aspect to the successful management of neutropenic sepsis (Mort et al., 2008). The local guideline from the regional cancer treatment centre included the following key emergency treatment steps (Haji-Michael, 2010). See Appendix 4.

1. Urgent triage category
2. Urgent full blood count (FBC)
3. Intravenous antibiotics within 1 hour (door to needle time).

This guideline printed off at the end of eTriage if the triage nurse considered neutropenic sepsis to be a possible presenting problem (See Appendix 4). It then formed part of the paper clinical record and was immediately available for the assessing clinician (as they would select the clinical record and take it to the bedside when assessing the patient). The three emergency treatment steps listed above were extracted from either the clinical record (triage category and timing of antibiotics) or the haematology database (timing of FBC). The management of patients with potential neutropenic sepsis was the secondary outcome measure within this research.

Two separate retrospective data collection strategies were developed for the triage cohort and the neutropenic sepsis cohort of patients. These will be described in turn.

#### *4.9.3 Data collection – Triage records*

On receipt of the randomised sample of eTriage records data collection began. A significant amount of demographic and clinical data was already captured by the hospital PAS database for all patients attending ED. It is useful to use existing health records data where possible (Polit & Beck, 2008). This data was easily accessible and saved a considerable amount of the researcher's time. Demographic data and mode of arrival did not have to be extracted manually from each record. For each of the eight study months a complete set of data for all patients that attended was extracted from the hospital's PAS database and exported into Microsoft Excel®. This was undertaken by the ED's information manager who firstly removed any patient identifiers: name, date of birth, address, postcode, NHS number. There are over 50 clinical fields captured for each patient, all were removed with the exception of the following:

- Attendance date and time
- District Number (this was required to retrieve the scanned clinical record)
- A&E number (e.g. 13/00001)
- Age
- Gender
- Mode of arrival (ambulance, car, bus, taxi, walked, bicycle, other)

The researcher then received eight Microsoft Excel® spread sheets, one for each of the study months, containing every patient that attended ED. For each month the attendances ranged from 6,451-7,267. Every record that was not part of the random sample for that month was deleted, leaving 120 attendances for analysis. This was repeated for each of the eight study months and once completed

rechecked for accuracy. Thirty non-randomised records from the first study month (April 2009) and the last month (January 2012) were added to an additional spreadsheet in order to pilot the data extraction procedures.

#### *4.9.4 Pilot data collection – Triage records*

Piloting data collection procedures is recommended as it allows the researcher to judge the robustness of the data collection tool and amend accordingly (Bruce et al., 2008). It is critical to ensure that the final procedure is clear, easy to use and unambiguous. This will contribute to the rigour, reliability and validity of the research (Polit & Beck, 2008). Another important feature of a pilot is to assess how manageable data collection is in terms of time and resources (Bruce et al., 2008). The researcher had to establish the time it took to analyse each record as all 800 were being done single-handedly. Prior to the pilot it was not known how realistic or feasible the analysis of 800 records was for a single researcher with a finite amount of time. A data extraction sheet was developed for the triage data collection pilot (see Appendix 10). The pilot (undertaken by the researcher) identified several useful observations which informed the final data collection strategy:

1. All records were available although some had not undergone a triage assessment as they were seen on arrival by a clinician.
2. The pre-eTriage records had missing information e.g. pain scores were not always recorded even though in some cases the patient received pain relief. The discriminator was absent in 8 records (27%).
3. It took on average 1 minute to complete the data extraction sheet for each record.
4. The process of then transferring the information from the data extraction sheet into the electronic database took additional time.

A pragmatic decision had to be made about the missing data and its subsequent coding identified by the pilot; in particular missing pain scores. National



guidelines identify which type of analgesic should be administered for a specific pain score (CEM, 2010a, 2010c, 2010b). An assessment could not be made regarding the appropriateness of pain relief if the level of pain had not been scored. Therefore all patients without a pain score, regardless of whether they were given analgesia were coded as not having received analgesia according to their pain score. If patients had already received analgesia or declined it these were coded “yes” as if they had had analgesia administered triage. Coding “no” would have been inaccurate.

With regard to the absence of a discriminator, this was coded as if it was incorrect. A decision about the overall accuracy of the triage priority was made based on the rest of the triage documentation using the MTS as the standard (Mackway-Jones et al., 2006). Finally, in terms of the feasibility of data collection by a single researcher, the initial analysis of the whole sample would take approximately 13.5 hours. To eliminate the extra time taken to transfer the manual data and the risk of transcription error from paper format to electronic the data was entered directly into the electronic database. See Appendix 11 for example.

Once the pilot was complete, amendments were made to the data collection procedures. Triage nurse experience was included and an electronic database was created for data collection (see Appendix 11). The data collection then took place over eight consecutive days; 100 records per day. This ensured consistency in the decisions and the coding of the data. The data was entered in the format of Yes/No. The data was then recoded to ensure that it was all in numerical format ready for analysis. See Appendix 12 for the coding values. When all the data was collected it was copied into one Microsoft Excel® spreadsheet. One final coding column for the intervention was added: pre-eTriage = 0 and post eTriage = 1. The data was then imported into SPSS (20.0) for analysis.

#### *4.9.5 Data Collection – neutropenic sepsis*

The data collection strategy for patients with neutropenic sepsis was relatively simple. A list of ED patients over the two required time spans (April 2009-March

2010 and April 2011-March 2012) with a neutrophil count of  $<1.0$  was extracted from the hospital haematology database. Each ED record was then analysed and the required data coded and entered into the Microsoft Excel© spreadsheet. Four patients were excluded as, although neutropenic, they were not on chemotherapy. See Appendix 14 for example of Microsoft Excel© spreadsheet and Appendix 15 for the coding values for this sample. This data was also exported into SPSS (20.0) ready for analysis.

#### **4.10 Internal validity**

The internal validity of a study is of paramount importance when investigating cause and effect. Experimental studies that have a high degree of internal validity are able to demonstrate with confidence that the intervention under investigation was responsible for the observed change (Polit & Beck, 2008). They manipulate the research environment to ensure that the control and intervention groups are identical in all respects except for the independent variable (Siriwardena, 2007; Polit & Beck, 2008). An ITS design was selected for this research as a means of enhancing this study's internal validity. This research considered issues of bias and the role of confounders early in its design thereby ensuring it makes a meaningful contribution to the current ED CCDSS knowledge base.

The following threats to internal validity were specifically addressed in the design of this study:

- *Selection bias* was addressed by randomising patients for inclusion during each of the time series study periods. The homogeneity of the pre and post eTriage groups was then assessed statistically.
- *Performance bias* was minimised as ED staff were unaware that the study was taking place.
- *Historical changes* can create a risk of bias, especially when studies have taken place over a long period of time. The effect of any concurrent changes that

took place during the study that could impact on the result will be analysed in the discussion chapter.

- *Detection bias* was assessed by undertaking inter-rater reliability testing. Additionally the data collection processes were consistent over the study period and undertaken by one person.
- *Attrition bias* would not be a threat to validity, as patients were not followed up. All clinical records were available as they were stored electronically.
- *Reporting bias* would not be a threat to validity as all the outcomes measures would be reported fully.
- *Regression to the mean* was addressed by the use of an ITS design. Single measures of the outcomes of interest were not taken. Multiple measures before and after the intervention enabled the underlying secular trend to be exposed.

Addressing issues of bias within the design of this study helped to minimise the effects of external influences that can distort results. ITS design is the most robust method possible within the time and financial constraints of this research (Eccles et al., 2003).

#### **4.11 Confounding variables**

A covariate, confounding or extraneous variable is one that could also have an effect on the outcomes of interest in a study (Polit & Beck, 2008). The inability to measure, control or even be aware of all the possible confounding variables in a quasi-experimental study can be a significant threat to establishing causality (Harris et al., 2006). Randomisation ensures that the control and intervention groups are as identical as possible so that any observed change can be attributed to the intervention (Greenhalgh, 2010). Randomisation spreads any confounding variables equally between the groups and balances any characteristics that could have an effect of the outcome (Bruce et al., 2008). A significant proportion of the studies within the literature review (n=12) did not discuss any confounding

variables (Day et al., 1995; Schriger et al., 2000; Dong et al., 2005; Asaro et al., 2006; Roukema et al., 2008; Jadav et al., 2009; Niemi et al., 2009; Carman et al., 2011; Drescher et al., 2011; Gibbs et al., 2012; Lim et al., 2012; Bond et al., 2013). When confounders were considered they were concerned with the following four areas:

1. Patient characteristics: age, gender, disease severity
2. Clinician characteristics, namely level of experience
3. Staffing levels
4. ED overcrowding

Of the studies that did address confounders the majority considered patient characteristics and of particular relevance to CCDSS research in ED; disease severity (Goergen et al., 2006; Buising et al., 2008; Kwok et al., 2009; Roy et al., 2009; Nelson, J et al., 2011; Raja et al., 2012; Britton et al., 2013; Dexheimer et al., 2013; Jones, B. et al., 2013). Only two studies considered the effect of the experience/seniority of the treating clinician in their analysis (Kwok et al., 2009; Britton et al., 2013). Studies concerned with assessing the impact of CCDSS on the timeliness of interventions e.g. time to antibiotics, should also consider ED overcrowding and staffing levels as being potential confounders. Two studies make a cursory mention of the effects of overcrowding on ED care (Dong et al., 2005; Lim et al., 2012). However, only the study by Bond et al (2013) analysed if overcrowding, determined by the time it took for the patient to be assessed by a doctor, contributed to any delays in sepsis care.

Within this research the role of confounders was considered from the outset. Firstly, the randomisation of patients into each of the time series data points before and after the introduction of eTriage would evenly spread confounders. Any differences between the pre and post eTriage groups were identified through statistical analysis. Secondly, with regard to clinician experience data was extracted and then coded for each triage episode that denoted the years of experience of the triage nurse. Logistic regression analysis was undertaken to

identify what relationships there were between the triage decisions and age, gender, mode of arrival, the experience of the triage nurse and eTriage

#### **4.12 External validity**

The external validity of a study is concerned with the degree to which the results can be generalised and applied to settings and samples beyond those in the research study (Polit & Beck, 2008). This study did not set out to demonstrate generalisable findings as it was evaluating a bespoke CCDSS developed specifically for use in one ED. Several of the critically appraised studies within this thesis identified limits to generalisability as they too had evaluated bespoke systems used in single departments (Melnick et al., 2010; Bond et al., 2013; Britton et al., 2013). Whilst the findings from this research will not be directly transferrable to other EDs as they do not have the same CCDSS, generalisable principles will be explored in the discussion chapter.

#### **4.13 Inter-rater reliability testing**

Inter-rater reliability assesses the degree with which individuals make the same decision about a characteristic that is being measured: the level of agreement (Polit & Beck, 2008). All the records were assessed and coded by the researcher who made assessments regarding the accuracy of the triage decisions and pain management. The accuracy and reliability of these judgements could be called into question. In order to establish how accurate these judgments were a subset of records were independently assessed and coded by a second person. Undertaking an inter-rater reliability test in this way was important as it enabled the overall reliability of the results to be established. The second person was an experienced emergency nurse from a neighbouring department. This nurse had over 20 years emergency nursing experience and had used the MTS for the last 10 years. She also used the CEM pain management standards as part of her everyday practice (CEM, 2010a). This emergency nurse was introduced to the research and taken through 10 records with the researcher to instruct her on the coding procedures. Following advice from the statistician a non-randomised sample of the first 10 records of each of the eight study months were extracted from the

original total months' attendances and anonymised. They were then coded directly into a database using the same data extraction procedures that were used in the research. In total 80 records were assessed by the second nurse who made decisions about:

1. Whether the clinical priority selected for the patient was correct
2. Whether the analgesia given was in line with the patient's pain score.

These two areas were selected as this data that required a judgment on the part of the coder. The data was exported from Microsoft Excel© into SPSS (20.0) ready for analysis. Cohen Kappa Coefficient scores are used to measure agreement and take into account agreement that could occur by chance (Pallant, 2007). Percentage agreement and Kappa scores were calculated for each of the above and enabled the validity of the data collection to be established.

#### **4.14 Data analysis**

The sets of data collected and analysed as part of this research were nominal. Nominal data is analysed using non-parametric statistical tests; these are frequently used to analyse medical data (Bruce et al., 2008). The sets of data from the triage cohort and the neutropenic sepsis cohort were analysed separately using SPSS (20.0). The descriptive statistics presented information about the samples and where relevant identify: age, gender, mode of arrival, time of arrival, triage nurse experience, early warning score and triage priority category. The presentation of descriptive statistics gives a general understanding of the data, the characteristics of the sample and frequencies that arise (Argyrous, 2007). They provided information about the main features of both datasets (triage and neutropenia) and allowed an analysis of the representativeness between the pre and post eTriage groups.

##### *4.14.1 Inferential statistics*

In quantitative research the use of inferential statistics allows conclusions to be drawn about the wider population from the sample analysed (Argyrous, 2007).

The questions of interest in this research centred around the evaluation of eTriage and its effect on quality and safety. Initial statistical tests will compare triage decisions and the management of patients with potential neutropenic sepsis before and after the introduction of eTriage. As the data is nominal and two samples were being compared (pre and post eTriage) Chi Square was used as this test analyses relationships between two groups (Pallant, 2007). The differences of interest between the pre and post eTriage groups were:

1. Triage prioritisation – which group had correct priorities most often
2. Pain assessment – which group had pain assessed most often
3. Pain management – which group was administered analgesia most often according to the established pain management guidelines and policies
4. Neutropenic sepsis management – which group adhered most often to the national guidelines for the initial management of patients with potential neutropenia:
  - a) Triage priority allocated “very urgent”
  - b) Full blood count taken within one hour
  - c) Timeliness of antibiotics.

This statistical analysis provided a simple before and after evaluation of the impact of eTriage. Despite its limitations, there is support for the use of this type of measurement, especially if there is a large effect with the intervention (Brown & Lilford, 2008). However, the use of Chi Square did not take into account the underlying secular trend or the effects of any confounding variables (Eccles et al., 2003). In order to increase the internal validity of the research, a statistical comparison of the trends over time and an analysis of confounding variables was required (Flodgren & Oddgard-Jensen, 2013). Based on the ITS study by Busing et al., (2008) logistic regression and time series analysis evaluated the changes and exposed the underlying secular trend.

#### **4.15 Logistic regression analysis**

Regression analysis is used to adjust for possible confounding variables and explain any possible relationship between them and the variable of interest (Polit & Beck, 2008). As the data in this study was nominal with two categories (yes/no), binary logistic regression was used (Field, 2009). A theoretical model for the logistic regression analysis was developed based upon the confounding variables identified in other studies (Kwok et al., 2009; Melnick et al., 2010; Nelson, J et al., 2011; Raja et al., 2012; Jones et al., 2013). The confounding variables that were addressed are:

- Age
- Gender
- Mode of arrival
- Triage nurse experience.

The aim of the regression analysis was to identify the effects of these other variables on the outcomes of interest: triage prioritisation (selection of: chart, discriminator and priority), pain scoring and appropriateness of analgesia. The regression analysis explored the relationship between the confounding variables included in the regression model and eTriage. The regression analysis enabled the identification of which variable: age, gender, mode of arrival, triage nurse experience and eTriage is the best predictor of accurate decision making at Triage. It identified which of the variables had a statistically significant effect on the outcomes of interest. The underlying secular trend was also exposed using a fitted model from the regression analysis. The next section of this chapter will address ethics and research governance prior to the final summary.

#### **4.16 Ethics and Research Governance**

Ethical approval for this study was obtained from the University of Salford Research Ethics panel in 2010. The information governance issues surrounding the collection of retrospective data was discussed and agreed by the hospital's



Caldicott Guardian. The protection of patient/clinical data was addressed and informed by the Data Protection Act (1998), guidance from the National Patient Safety Agency (2010), common law and the professional duty to protect confidentiality. No directly identifiable patient information was stored e.g. name, date of birth, address or NHS number. Two numerical identifiers, used to enable the clinical records to be retrieved from hospital databases, were stored on two separate databases (Microsoft Excel © and SPSS 20.0). Both databases were password protected and only accessible by the researcher. Once the research is complete the databases will be archived according to University of Salford and National Health Service regulations. No paper-based data was collected. The National Research Ethics Service was contacted on 14/01/2011 about this proposed research (See Appendix 16). NHS Ethical approval was not required as there was no risk posed to patients. The National Research Ethics Service viewed this study as service evaluation (NRES Ethics Consultation E-Group, 2007). It was not practical, feasible or deemed necessary to obtain consent from patients for this research. eTriage was a planned service development; if this study had not taken place the benefits or otherwise would not be known.

#### **4.17 Summary**

This research study used an ITS design to identify if decisions made when a CCDSS was introduced improved quality and safety in the ED. The methods used have addressed aspects of internal validity and the impact of confounding variables to ensure a rigorous approach. Retrospective data from ED clinical records was extracted, coded and analysed using descriptive and inferential statistics. The next chapter presents the results of the descriptive and statistical analysis of the triage cohort and the neutropenic sepsis cohort.

## CHAPTER 5: RESULTS

### 5.1 Introduction

This chapter presents the results of a quasi-experimental study that adopted an ITS design to answer the following research question: *Does the introduction of a computerised clinical decision-support system eTriage improve the quality of triage decisions and safety within the ED?*

### 5.2 Outcome measures

The primary outcome measure assessed the safety and quality of the triage decision-making process. This was assessed by establishing the following:

- a. The accuracy of the triage prioritisation process
- b. The assessment of pain – by allocation of a pain score
- c. The appropriate management of any pain identified at triage – by adhering to pain management guidelines (See Appendices 8 & 9)

The secondary outcome measure is concerned with patient safety and assessed the management of patients that presented with possible neutropenic sepsis. Appropriate management was judged by assessing the following:

- a. Triage priority allocated as “very urgent”
- b. Full blood count taken within one hour
- c. Timeliness of antibiotics

Two separate datasets have been analysed to enable the outcome measures to be evaluated.

- Firstly, using an ITS design, data from 800 triage records (400 before the launch of eTriage and 400 after) were extracted and coded. Analysis of this triage dataset enabled the impact of the CCDSS on the primary outcome measure to be assessed.

- Secondly, a whole population sample was used to analyse the impact of eTriage on patients that presented to ED with possible neutropenic sepsis. Data was extracted and coded from the clinical record for all patients who presented during the two study periods, pre and post eTriage. Analysis of this neutropenic sepsis dataset enabled the impact of the CCDSS on the secondary outcome measure to be assessed.

Each dataset is dealt with in turn and the descriptive and inferential statistics are presented. Firstly missing data and then results of the inter-rater reliability testing is presented. The impact of confounding variables within the triage dataset is addressed by logistic regression analysis. The underlying trend in decision-making is also exposed with the regression analysis.

### **5.3 Missing data**

As every ED clinical record was stored electronically there were no instances of the record not being available for analysis. However, once the clinical records for the triage cohort were retrieved two types of missing data were identified. The first type of missing data was anticipated in the planning of this study and is concerned with those patients who did not undergo a triage assessment at all. When the ambulance service issues a “pre-alert” to the ED, the clinical team is assembled and remains on “standby” until the patient’s arrival. These “standby” patients are assessed and treated immediately and therefore they do not require a triage assessment. Additionally, at times of low demand there may be no wait to see a clinician. If this is the case immediately after registration the patient is assessed directly by a clinician, again negating the need for a triage assessment. There were instances of both of these situations in the pre and post eTriage groups. In the pre-eTriage group there were 27 instances of patients not undergoing a triage assessment, in the post-eTriage group there were 44 instances. As this had been expected and advice from a statistician sought, data collection continued until data had been extracted from 100 records, where the patient had undergone a Triage assessment. This was repeated per time series month.

The second type of missing data was identified in the pre-eTriage cohort and this relates to absent data. Several omissions in the triage record were first recognised during the pilot data collection exercise. As with any paper-based clinical record data can be incomplete if sections are missed out (Worster & Haines, 2004). The post-eTriage data was complete as the CCDSS did not allow the triage nurse to omit any of the fields. However this was not the case with the pre-eTriage group and some pragmatic decisions were made after discussion with the statistician regarding the missing data identified during the whole data collection process.

In the pre-eTriage group there was missing data in the following areas

- Triage nurse (no signature or unable to read the signature)
- Right chart (no chart recorded, area left blank)
- Right discriminator (no discriminator documented, area left blank)
- Right priority (no priority assigned to the patient, priority not circled)
- Pain score (no pain score recorded, pain score not circled)
- Analgesia (no analgesia administered despite a pain score of 1 or more, area to record drugs administered left blank)

The absent triage nurse data (n=89) was coded as missing. In the five other cases of missing data listed above they were all coded as “no”. If the data had been coded as missing it would not have been included in the analysis (Pallant, 2007). The accuracy of the record was an important element that warranted exposure. Missing data and the possible impact on the results will be analysed in the discussion chapter.

#### **5.4 Inter-rater reliability testing**

Inter-rater reliability testing has been undertaken to establish the degree of concordance between the scores assigned to the data by the researcher and an independent experienced ED senior nurse. The independent “rater” reviewed 80

triage records (40 pre eTriage and 40 post eTriage) and was asked to judge the following

1. The correctness of the priority
2. The appropriateness of the analgesia given based on the patient's pain score, using the CEM pain management standards (CEM 2010b, 2010c). See Appendices 8 & 9.

The judgements were compared with those of the researcher to establish the degree of homogeneity and are presented below in Tables 5.1 & 5.2

Table 5.1 Was the correct clinical priority selected for the patient?

% agreement	Cohen's Kappa Coefficient Score	Statistical significance
95.5%	0.51	p <0.001

Table 5.2 Was the analgesia give appropriate, based on the pain score?

% agreement	Cohen's Kappa Coefficient Score	Statistical significance
80.9%	0.67	p <0.001

#### *5.4.1 Interpretation of kappa score for inter-rater reliability*

The kappa statistic takes into account agreement that may occur by chance and is therefore viewed as a more reliable measure than the observed percentage agreement (Peat & Barton, 2005). A score of 1 shows perfect agreement and a score of 0 represents agreement that would occur by chance (Viera & Garrett, 2005). A commonly cited interpretation of kappa and the one used in this research is described in Table 5.3

Table 5.3 Interpretation of kappa (Landis & Koch, 1977)

<b>Kappa</b>	<b>Agreement</b>
<0	Less than chance
0.01-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-0.99	Almost perfect

Table 5.1 identifies a kappa score of 0.51 demonstrating moderate agreement between the researcher and the independent rater. Table 5.2 identifies a kappa score of 0.67 which demonstrates a substantial agreement between the two raters. However, there is a very high observed percentage agreement between both raters (95.5% & 80.9%).

## **5.5 Triage dataset**

The triage dataset contains data extracted from 800 records: 400 before the introduction of eTriage and 400 one year after its launch. This section will describe the results of the descriptive and statistical analysis.

### *5.5.1 Results of the descriptive analysis of the triage data*

The following descriptive statistics summarise the main features of the triage data using bar charts and allow a comparison between the pre and post eTriage cohorts for: age, gender, time of arrival, mode of arrival, triage priority, stream (minors, majors) and triage nurse experience. As the data is categorical/nominal a non-parametric test; Chi Square is used to identify any statistically significant differences between the pre and post eTriage groups. Statistical significance has been set at  $p < 0.05$

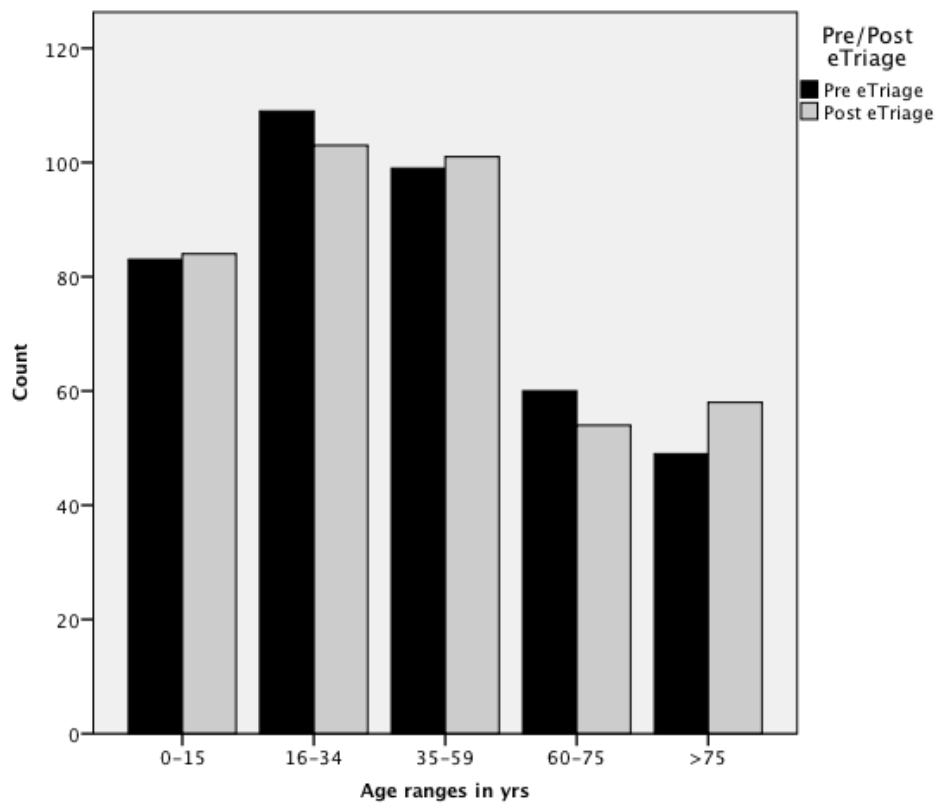


Figure 5.1 Age ranges in the pre and post eTriage groups – triage cohort

Table 5.4 Age range percentages in the pre and post eTriage groups – triage cohort

	0-15yrs	16-34yrs	35-59yrs	60-75yrs	>75yrs
Pre eTriage	20.8%	27.3%	24.8%	15.0%	12.2%
Post eTriage	21.0%	25.8%	25.2%	13.5%	14.5%

$$\chi^2 = 1.269; p=0.87$$

There was no statistically significant difference in the ages of patients in the pre and post eTriage groups.

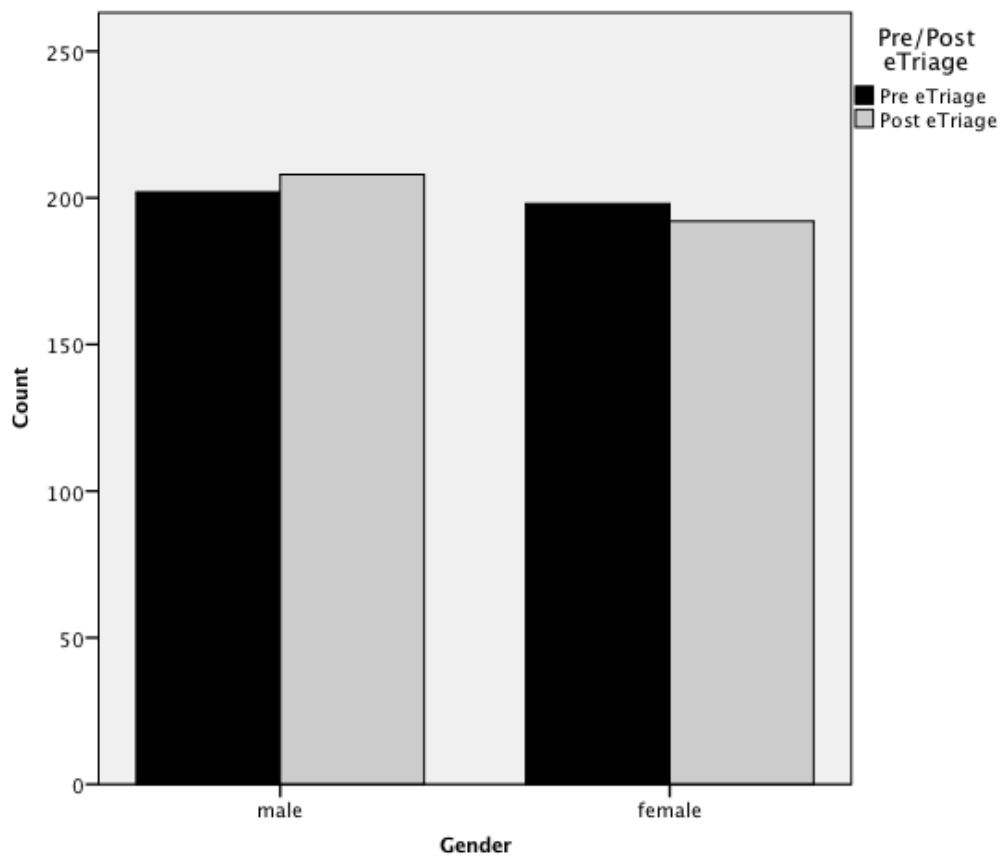


Figure 5.2 Gender in the pre and post eTriage groups- triage cohort

Table 5.5 Gender percentages in the pre and post eTriage groups – triage cohort

	Male	Female
Pre eTriage	50.5%	49.5%
Post eTriage	52.0%	48.0%

$$\chi^2 = 0.125; p=0.72$$

There was no statistically significant difference in the gender of patients in the pre and post eTriage groups.



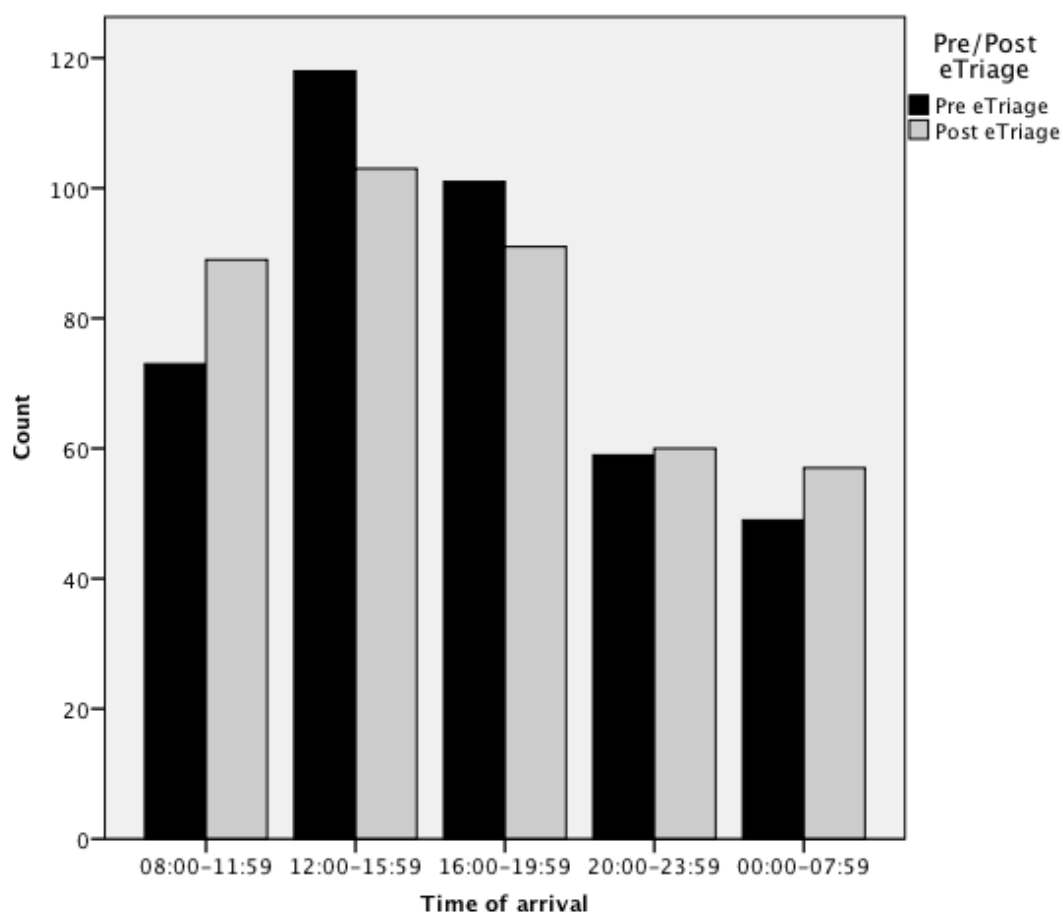


Figure 5.3 Time of arrival in the pre and post eTriage groups – triage cohort

Table 5.6 Time of arrival percentages in the pre and post eTriage groups – triage cohort

	<b>08:00-11:59</b>	<b>12:00-15:59</b>	<b>16:00-19:59</b>	<b>20:00-23:59</b>	<b>00:00-07:59</b>
Pre eTriage	18.2%	29.5%	25.2%	14.8%	12.2%
Post eTriage	22.2%	25.8%	22.8%	15.0%	14.2%

$$\chi^2 = 3.371; p=0.44$$

There was no statistically significant difference in the time of arrival of patients in the pre and post eTriage groups.

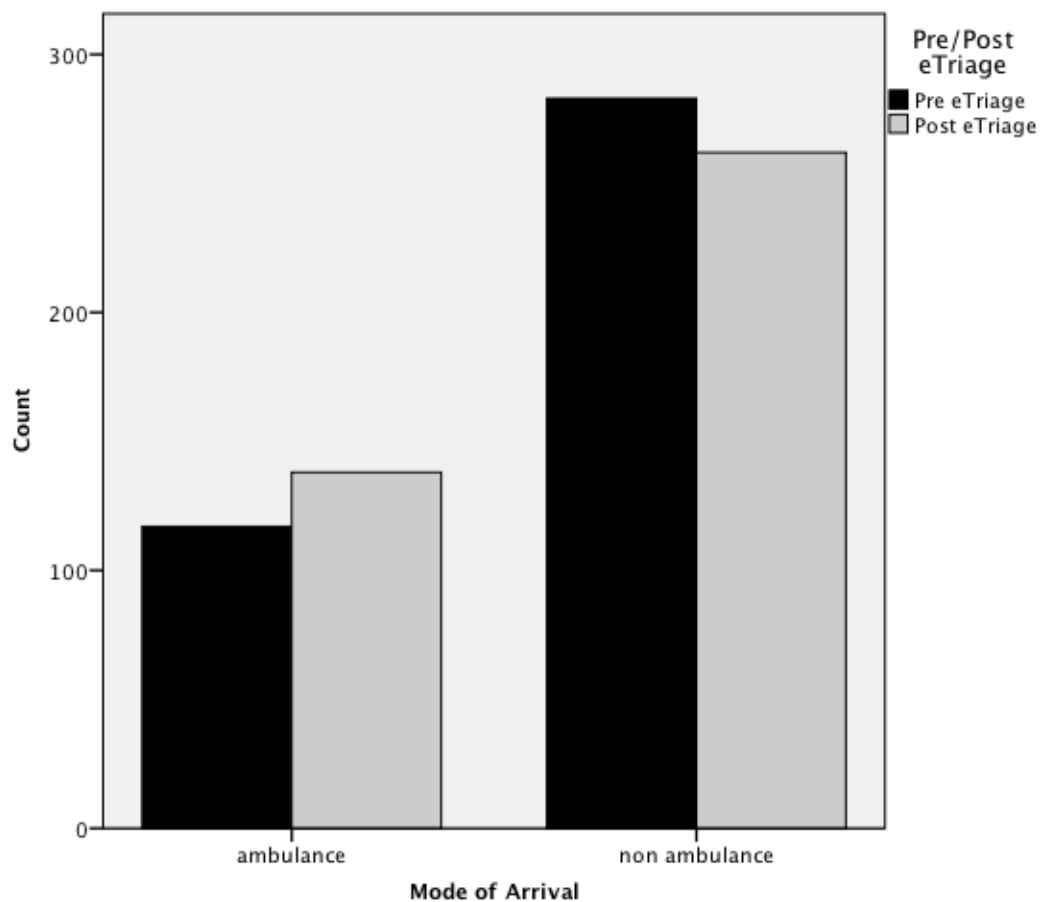


Figure 5.4 Mode of arrival in the pre and post eTriage groups – triage cohort

Table 5.7 Mode of arrival percentages for the pre and post eTriage groups – triage cohort

	Ambulance	Non-Ambulance
Pre eTriage	29.2%	70.8%
Post eTriage	34.5%	65.5%

$$\chi^2 = 2.303; p=0.12$$

There was no statistically significant difference in the mode of arrival of patients in the pre and post eTriage groups.

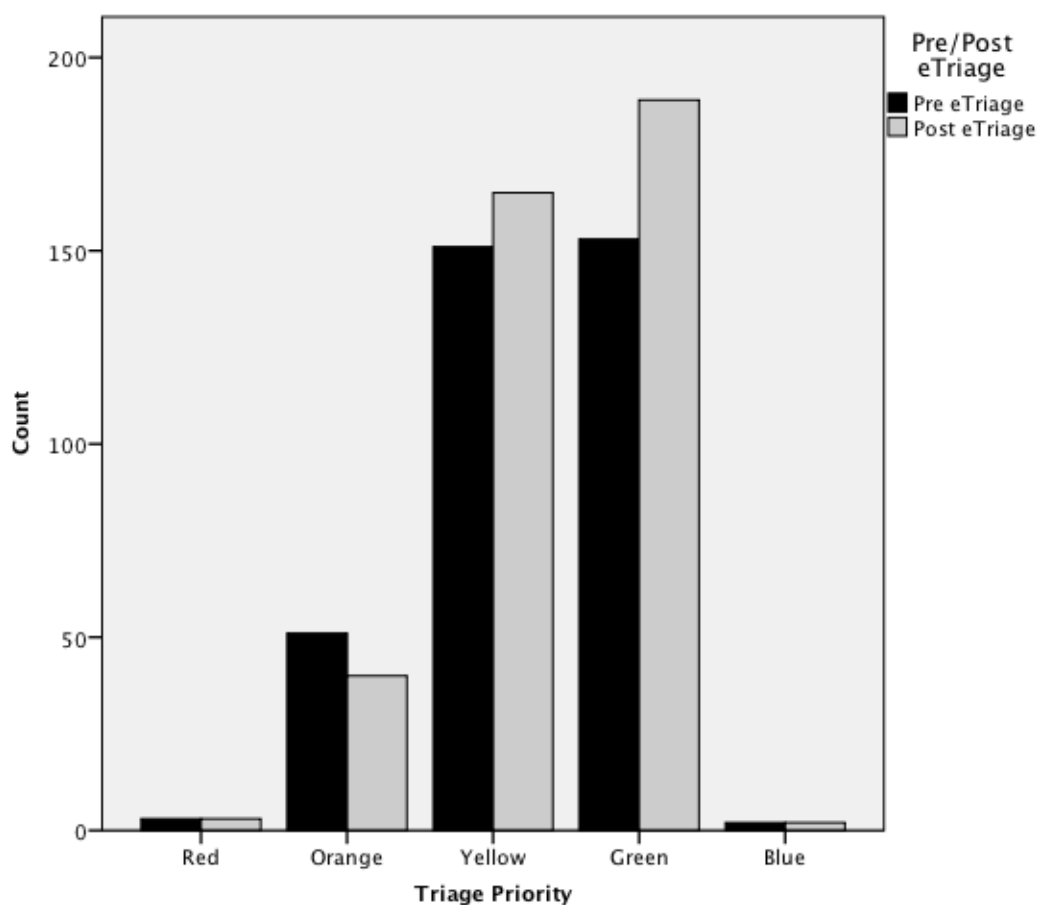


Figure 5.5 Triage priority category in the pre and post eTriage groups – triage cohort

Table 5.8 Triage priority categories in the pre and post eTriage groups - triage

	Red	Orange	Yellow	Green	Blue
Pre eTriage	0.8%	14.2%	41.9%	42.5%	0.6%
Post eTriage	0.8%	10.0%	41/4%	47.4%	0.5%

$$\chi^2 = 3.745; p=0.44$$

Missing data n=41 in the pre eTriage group.

There was no statistically significant difference in the triage priority category allocated to patients in the pre and post eTriage groups.

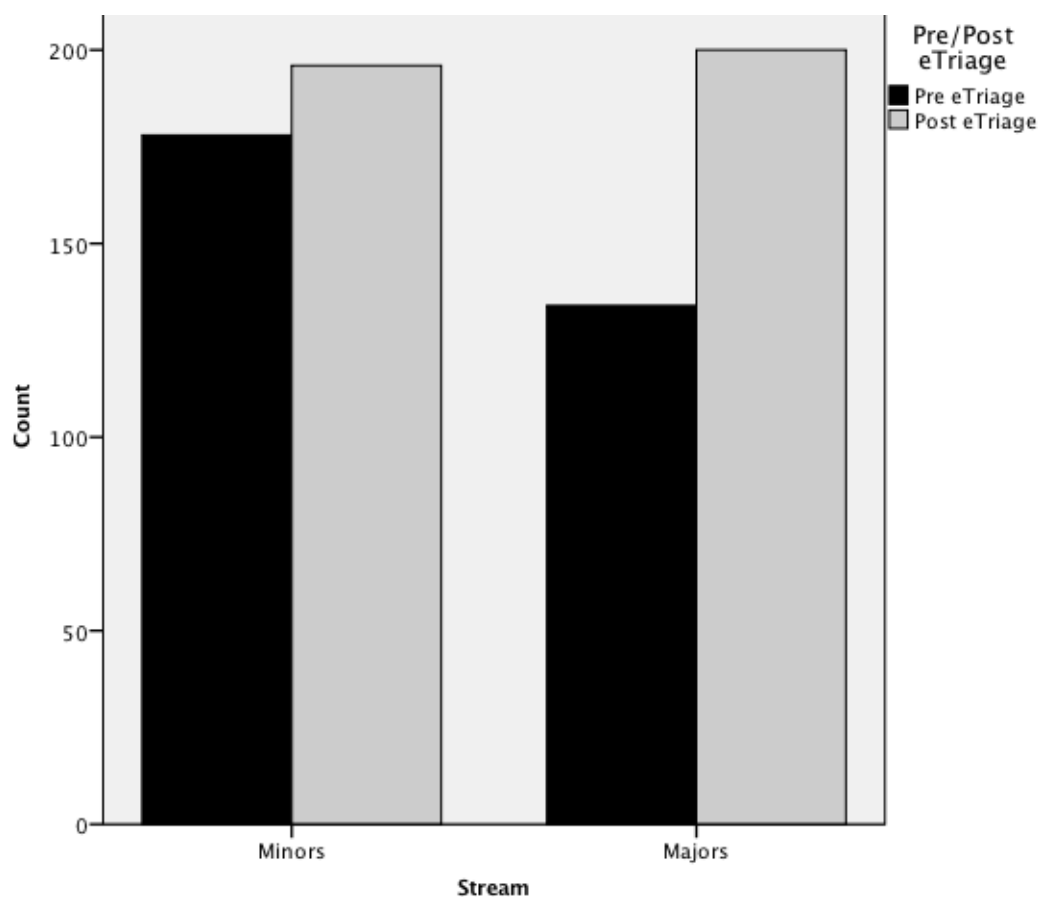


Figure 5.6 Stream in the pre and post eTriage groups – triage cohort

Table 5.9 Stream percentages in the pre and post eTriage groups – triage cohort

	Minors	Majors
Pre eTriage	57.1%	42.9%
Post eTriage	49.5%	50.5%

$$\chi^2 = 3.701 \text{ } p=0.05$$

Missing data n=5 in the pre eTriage group.

There was a slightly statistically significant difference in the stream allocated to patients in the pre and post eTriage groups with more majors patients post eTriage.

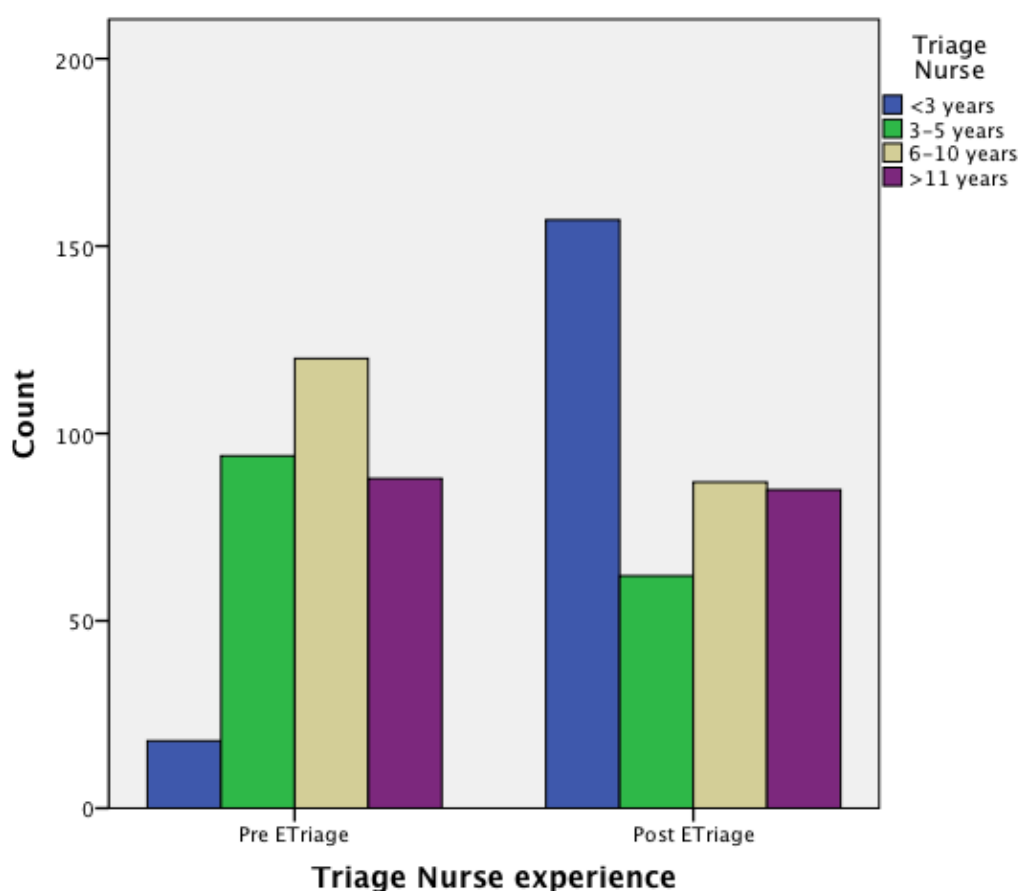


Figure 5.7 Triage nurse experience in the pre and post eTriage groups – triage cohort

Table 5.10 Triage nurse experience percentages in the pre and post eTriage groups – triage cohort

	<3yrs	3-5yrs	6-10yrs	>11yrs
Pre eTriage	5.6%	29.4%	37.5%	27.5%
Post eTriage	40.2%	15.9%	22.3%	21.7%

$$\chi^2 = 116.35 \text{ } p < 0.001$$

Missing data n=89 in the pre eTriage group (either missing or illegible).

There is a statistically significant difference in the experience of the triage nurse in the pre and post eTriage groups with more junior staff post eTriage.

### *5.5.2 Summary of the triage descriptive statistics*

The above descriptive statistics have compared the pre and post eTriage groups and facilitate descriptions of the characteristics of the sample. They also allow a comparison of the pre and post eTriage samples to identify differences, which maybe of significance to this study. When the pre and post eTriage samples were compared there is no statistically significant difference in: age, gender, time of arrival, mode of arrival or triage priority as all evidenced by p values of  $> 0.05$ . However in the pre eTriage group the priority was not recorded in  $n=41$  cases. There is a borderline statistical significance between the streams allocated: major or minor ( $p = 0.05$ ). There were  $n=5$  missing streams recorded in the pre eTriage group; this may have had the potential to change the statistical significance. Of importance is the marked difference between the experience of the triage nurses in the post eTriage group ( $p < 0.001$ ). However there were a significant number of missing values in the pre eTriage group. In  $n=89$  of the records there was no signature or an illegible one. Experience of the triage nurse has been identified as a possible confounder in chapter 4. Whether triage nurse experience had an independent effect of decision-making at triage will be addressed through the logistic regression analysis in section 5.6

### *5.5.3 Results of the inferential statistical analysis of the triage data*

Inferential statistics have been used to compare the differences in decision-making before and after the introduction of eTriage. Again as the data is categorical/nominal a non-parametric test, Chi Square is used. This initial analysis has been undertaken to identify any differences and how substantial they are before the logistic regression considers confounders and the underlying decision-making trend.

The following results compare the pre and post eTriage cohorts for

- Triage prioritisation – which group had the most correct priorities
- Selection of the correct triage chart

- Selection of the correct discriminator
- Pain assessment – which group had pain assessed more frequently
- Pain management – which group received analgesia according to established pain management guidelines and policies

### Triage prioritisation

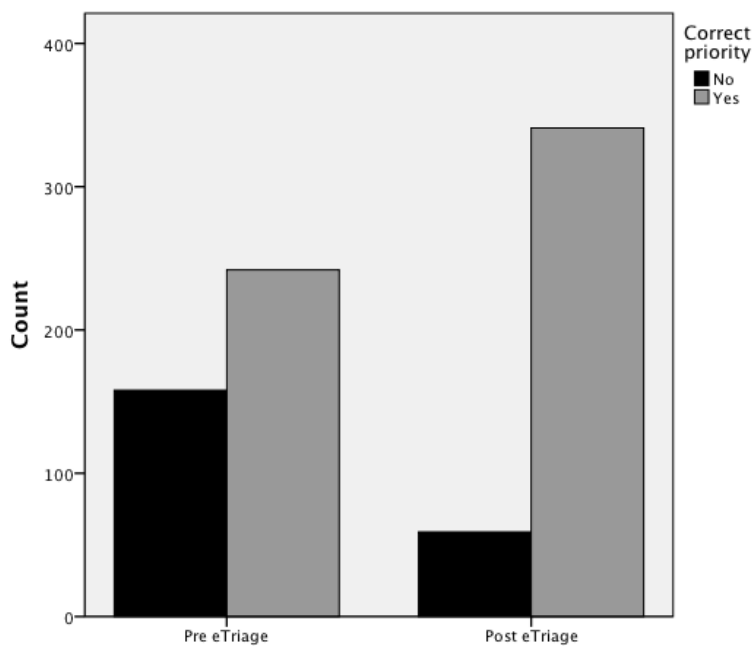


Figure 5.8 Correct priority in the pre and post eTriage groups

Correct triage prioritisation pre eTriage was 60.5% versus 85.2% post eTriage

$$\chi^2 = 60.70; p < 0.001$$

There is a highly statistically significant difference between the pre and post eTriage groups. Patients are more likely to be triaged correctly when eTriage is used.

### Selection of the correct triage chart

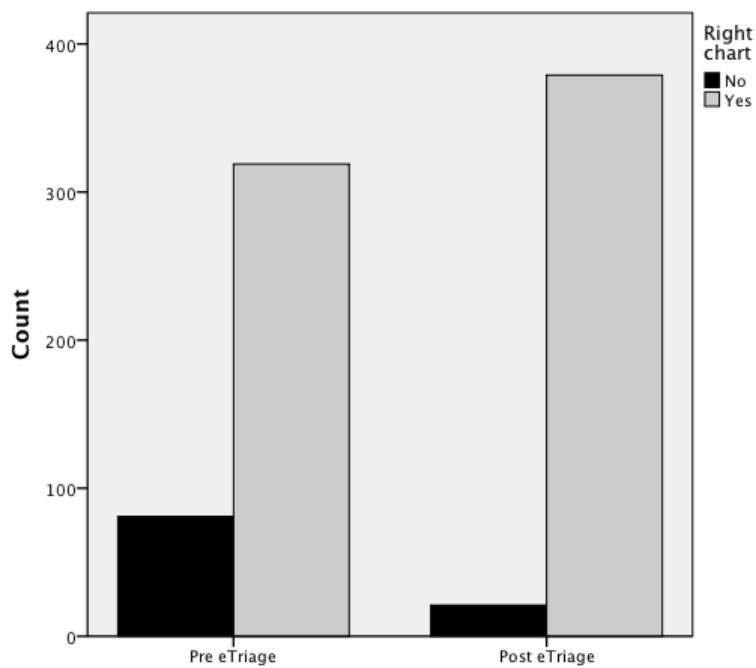


Figure 5.9 Selection of the correct triage chart in the pre and post eTriage group

Correct triage chart selection pre eTriage was 79.8% versus 94.8% post eTriage

$$\chi^2 = 39.11; p < 0.001$$

There is a highly statistically significant difference between the pre and post eTriage groups. Triage Nurses are more likely to select an appropriate triage chart when eTriage is used.



### Selection of the correct discriminator

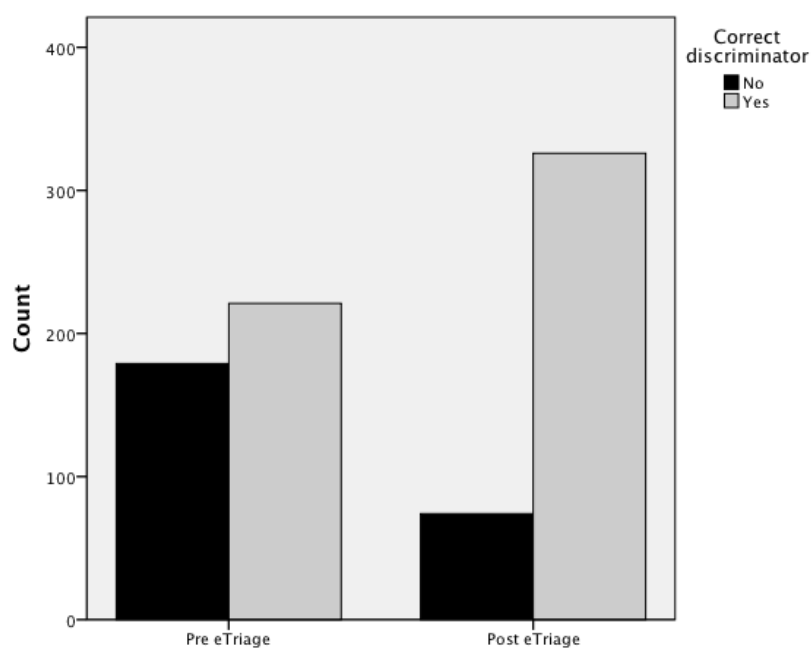


Figure 5.10 Selection of the correct discriminator in the pre and post eTriage group

Correct triage discriminator pre eTriage was 55.2% versus 81.5% post eTriage

$$\chi^2 = 62.52; p < 0.001$$

There is a highly statistically significant difference between the pre and post eTriage groups. Triage nurses are more likely to select the correct triage discriminator when eTriage is used.

## Pain assessment

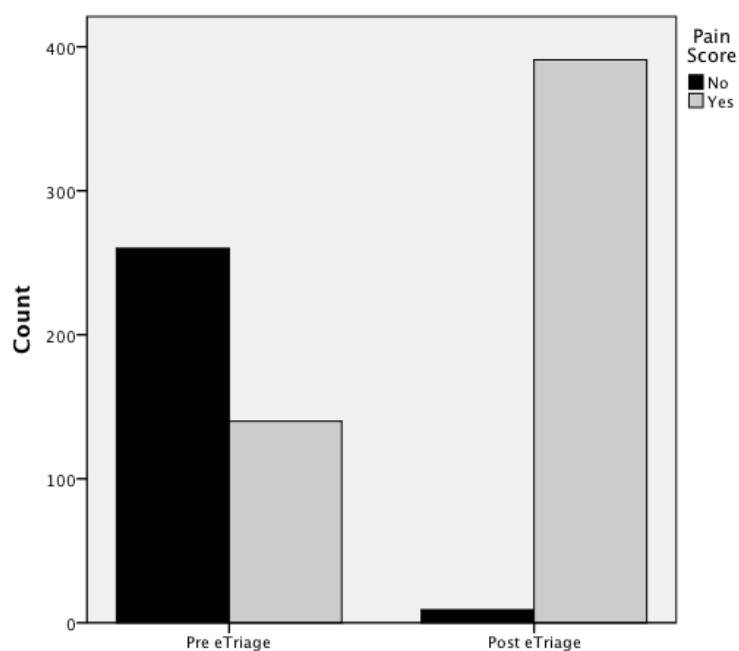


Figure 5.11 Pain scoring in the pre and post eTriage groups

Pain assessment pre eTriage was 35% versus 97.8% post eTriage

$$\chi^2 = 350.04; p < 0.001$$

There is a highly statistically significant difference between the pre and post eTriage groups. Patients are more likely to have their pain assessed when eTriage is used.

## Pain management

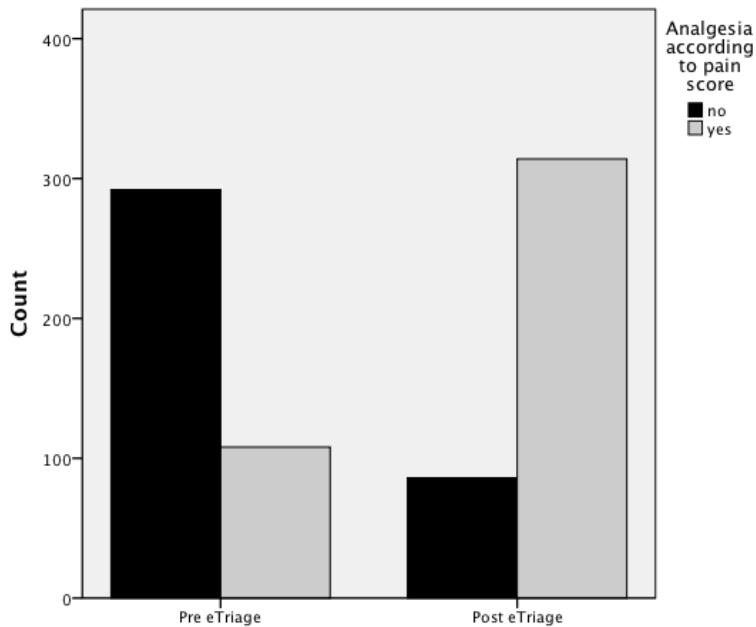


Figure 5.12 Appropriate analgesia in the pre and post eTriage groups

Appropriate analgesia administration pre eTriage was 26.6% versus 78.5% post eTriage

$$\chi^2 = 216.80; p < 0.001$$

There is a statistically significant difference between the pre and post eTriage groups. Patients are more likely to have appropriate pain relief administered when eTriage is used.

#### *5.5.4 Summary of the triage inferential statistics*

There are highly statistically significant differences between the pre and post eTriage groups with p values  $<0.001$  for all five areas of decision-making considered within the triage data. The observed percentage changes are also significant, in particular selection of the right chart (94.8%) and pain scoring (97.8%) reach near to 100%. Large effects such as these are purported to provide convincing evidence on their own of effectiveness (Brown & Lilford, 2008). However, further statistical analysis has been undertaken to investigate the role of any confounding variables. Time series analysis has revealed the underlying trend and enables some estimates of decision-making to be hypothesized if the intervention had not been introduced. These are presented in the next section.

### **5.6 Logistic regression analysis**

The binary logistic regression that is presented here has been based on the methods used by Buisson et al. (2008). The variables: age, gender, mode of arrival, triage nurse experience and the intervention (eTriage) were entered into the regression model, see Table 5.11 for an example of the regression model. The regression analysis has enabled an exploration of the effects of all these variables on the accuracy of decision-making. It has identified which of the variables is the best predictor of the outcome of interest and the relative importance of each of them on accurate decision-making. Additionally, to expose the underlying trend two new variables have been added. One considers the effect of time from the start of the study period (in months) and is called “month”. The other is the interaction between time and the intervention, called “intervention by month”. This enables the impact of time on the intervention, eTriage to be assessed by exposing the underlying trend.

#### *5.6.1 Logistic regression analysis for correct discriminator*

Table 5.11 below presents the results of the logistic regression model for correct discriminator

**Table 5.11 Logistic regression analysis for correct discriminator**

	Significance	Odds ratio	95% Confidence Interval	
			Lower	Upper
Age	0.512	1.002	0.995	1.009
Gender	0.551	0.901	0.639	1.269
Mode of arrival	<0.001	2.340	1.573	3.480
Triage nurse experience	0.498	1.061	0.894	1.259
Month (time series)	0.452	1.026	0.959	1.099
Intervention	0.004	29.763	2.946	300.729
Intervention by month	0.077	0.910	0.820	1.010

In Table 5.11 mode of arrival and eTriage both have p values of < 0.05 which demonstrates that each have a predictive effect for the selection of the correct discriminator when the other variables are controlled for.

Standardising age, gender, mode of arrival and triage nurse experience over the whole period of the study to the "average" patient/hospital characteristics of the whole cohort, the fitted percentages from the logistic regression model are:

#### **Correct discriminator**

Pre eTriage are: 0: 3 : 6 : 9 months 52.8%: 54.7%: 56.6%: 58.5%

Post eTriage are: 24: 27 : 30 : 33 months 86.7%: 84.1%: 81.2%: 77.9%

Figure 5.13 below illustrates the above fitted decision-making trends for the selection of the correct discriminator over time. In the pre eTriage period there is no statistical evidence of any trend in the "correct discriminator" (p=0.45) (percentage depicted by the solid line). Immediately post eTriage (24 months), there is a much greater "correct discriminator" percentage than expected from the pre eTriage period. See extrapolation point on Figure 5.13 below (expected

with no intervention effect = 67.6% vs fitted 86.7%). The extrapolation point demonstrates a hypothetical continuing upward trend which is still well below the baseline for eTriage. There is some slight evidence of a small decrease in the “correct discriminator” percentage over the period post eTriage; depicted by the dotted line ( $p=0.07$ ).

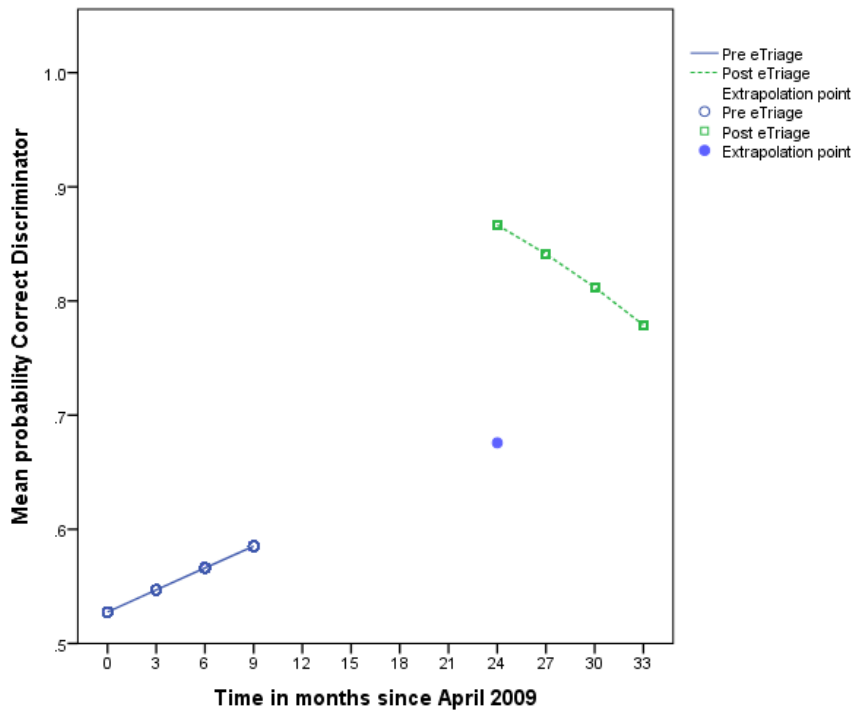


Figure 5.13 Fitted time trends for correct discriminator

### 5.6.2 Logistic regression analysis for correct priority

Table 5.12 below represents the results of the logistic regression model for correct priority

**Table 5.12 Logistic regression analysis for correct priority**

	Significance	Odds ratio	95% Confidence Interval	
			Lower	Upper
Age	0.398	1.003	0.996	1.011
Gender	0.353	0.843	0.589	1.208
Mode of arrival	0.001	1.962	1.298	2.965
Triage nurse experience	0.863	0.984	0.823	1.178
Month	0.963	1.002	0.934	1.074
Intervention	0.034	14.499	1.221	172.228
Intervention by month	0.354	0.949	0.851	1.059

In Table 5.12 again, mode of arrival and eTriage both have p values of < 0.05 which demonstrates that each have a predictive effect for the selection of the correct priority when the other variables are controlled for.

Standardising age, gender, mode of arrival and triage nurse experience over the whole period of the study to the “average” patient/hospital characteristics of the whole cohort, the fitted percentages from the logistic regression model are:

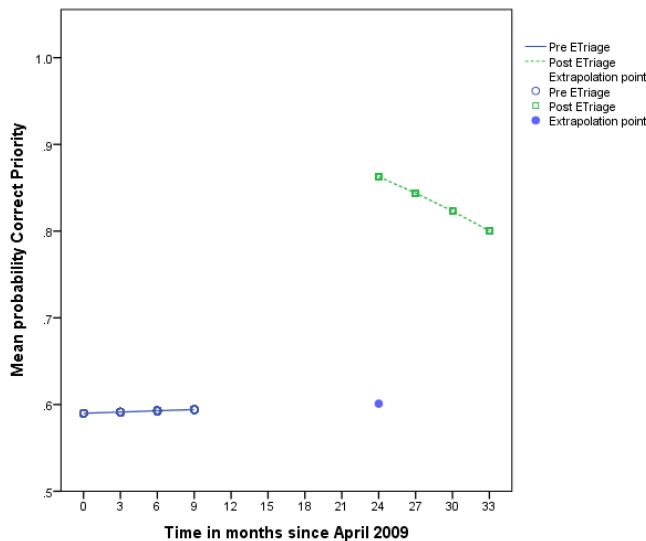
### **Correct priority**

Pre eTriage are: 0: 3 : 6 : 9 months 59.0%: 59.1%: 59.3%: 59.4%

Post eTriage are: 24: 27 : 30 : 33 months 86.3%: 84.4%: 82.3%: 80.0%

Figure 5.14 below illustrates the fitted trends for the selection of the correct priority over time. In the pre eTriage period there is no evidence of any trend in the “correct priority” percentage, depicted by the solid line ( $p=0.96$ ). Immediately post eTriage (24 months), there is a much greater “correct priority” percentage than expected from the pre eTriage period. See extrapolation point on Figure 5.14 below, (expected with no intervention effect = 60.1% vs fitted 86.3%). The

extrapolation point does not demonstrate any hypothetical continuing upward trend. There is no statistical evidence of any trend in the “correct priority” percentage over the period post eTriage, depicted by the dotted line. However the decline noted in Figure 5.14 was not statistically significant ( $p = 0.35$ ).



**Figure 5.14 Fitted time trends of correct priority**

### 5.6.3 Summary of the logistic regression analysis

The results of this logistic regression demonstrate that both the mode of arrival and eTriage have a positive influence on the correct decision-making at triage. Interestingly the experience of the triage nurse has not been identified as a confounding variable. The effects of mode of arrival will be considered in the discussion chapter.

### 5.6.4 Further analysis

Further logistic regression was planned but was not possible for the following data:

- Selection of the right chart
- Pain scoring



- Analgesia according to pain score

This was due to the very small numbers post eTriage; percentages were near to 100. These small numbers meant that the development of a robust regression model was not mathematically possible.

Therefore, further analysis will just present the observed percentages for: right chart, pain score and appropriate analgesia over time. The impact of the experience of the triage nurse is presented in section 5.6.5

### Right chart

Pre eTriage are: 0: 3 : 6 : 9 months 75.0%: 78.0%: 82.0%: 84.0%

Post eTriage are: 24: 27 : 30 : 33 months 98.0%: 95.0%: 93.0%: 93.0%

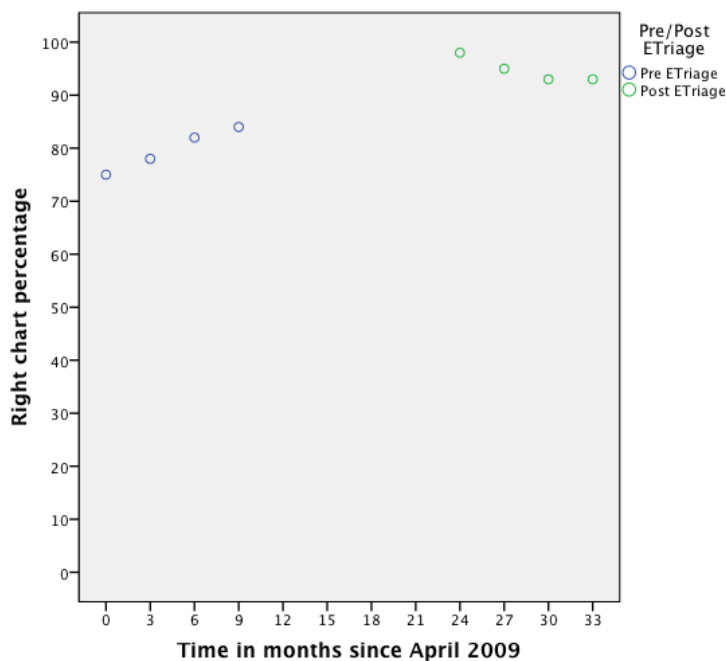


Figure 5.15 Observed time trends for right chart

## Pain Score

Pre eTriage are: 0: 3 : 6 : 9 months 34.0%: 30.0%: 41.0%: 35.0%

Post eTriage are: 24: 27 : 30 : 33 months 98.0%: 99.0%: 98.0%: 96.0%

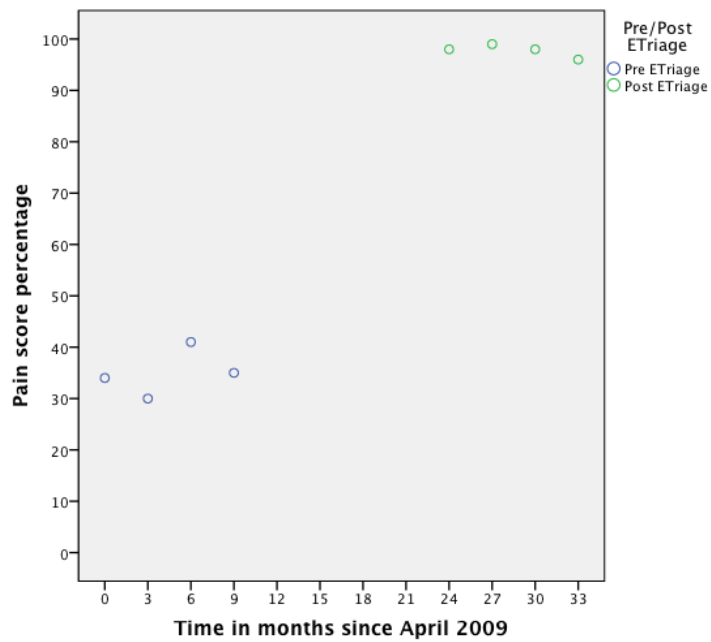


Figure 5.16 Observed time trends for pain score

### Analgesia according to score

Pre eTriage are: 0: 3 : 6 : 9 months 19.0%: 25.0%: 33.0%: 28.0%

Post eTriage are: 24: 27 : 30 : 33 months 73.0%: 83.0%: 76.0%: 83.0%

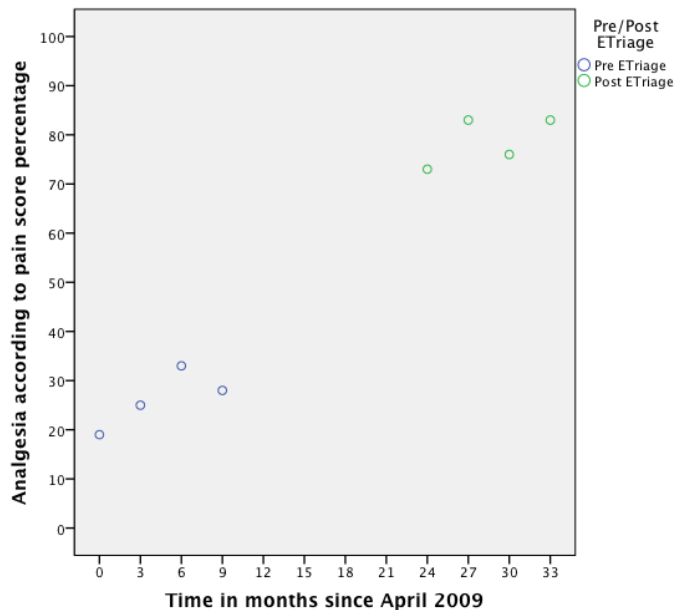


Figure 5.17 Observed time trends for analgesia according to pain score

These observed percentages demonstrate the trends over time. For the right chart and pain score post eTriage groups there is almost 100% accuracy in decision-making.

#### 5.6.5 Triage nurse experience

Clinician experience has been identified in previous studies as a confounding variable (Kwok et al., 2009; Britton et al., 2013). There was a statistically significant difference between the experience of the triage nurses in the pre and post eTriage cohorts  $p < 0.001$  (See Table 5.10). But interestingly the regression analysis in this study does not demonstrate any relationship between the experience of the triage nurse and the accuracy of decision-making. Although further regression has not been possible the following Tables 5.13, 5.14 & 5.15

consider the percentage of inexperienced triage nurses (<6 years experience) and experienced triage nurses (6 or more years of experience) who: select the right chart, record a pain score and give appropriate analgesia.

Table 5.13 Triage nurse experience and right triage chart selection pre and post eTriage

<b>Right chart selected</b>	Inexperienced triage nurse	Experienced triage nurse
Pre eTriage	78.6%	82.7%
Post eTriage	93.6%	96.5%

Table 5.14 Triage nurse experience and pain scoring pre and post eTriage

<b>Pain Scored</b>	Inexperienced triage nurse	Experienced triage nurse
Pre eTriage	35.7%	38.9%
Post eTriage	99.5%	97.1%

Table 5.15 Triage Nurse experience and appropriate analgesia pre and post eTriage

<b>Analgesia given according to Score</b>	Inexperienced triage nurse	Experienced triage nurse
Pre eTriage	31.2%	27.4%
Post eTriage	83.6%	73.8%

These percentages suggest that when eTriage was used the decision-making abilities of both inexperienced and experienced triage nurses greatly improve.

#### *5.6.6 Summary of the results from the triage dataset*

The results from the triage dataset demonstrate a statistically significant impact of eTriage on the primary outcome measures namely:

- a. The accuracy of triage prioritization
- b. The assessment of pain
- c. The appropriate management of pain identified at triage

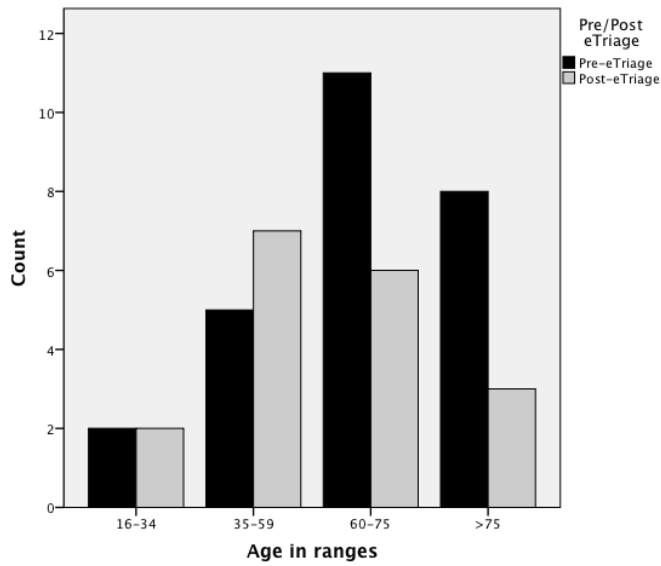
The final section of this chapter will consider the results from the neutropenic sepsis dataset which address the secondary outcome measure.

## **5.7 Neutropenic Sepsis dataset**

The initial neutropenic sepsis total population sample was 48; these patients had laboratory confirmed neutropenia. However four patients were excluded from all the analysis as they were not on chemotherapy and neutropenic for another reason. Of the 44 patients remaining 26 patients were from the first study period (April 2009-March 2010), prior to eTriage and the remaining 18 patients attended in the year after eTriage had been in place (April 2011-March 2012).

### *5.7.1 Descriptive statistics – neutropenic sepsis data*

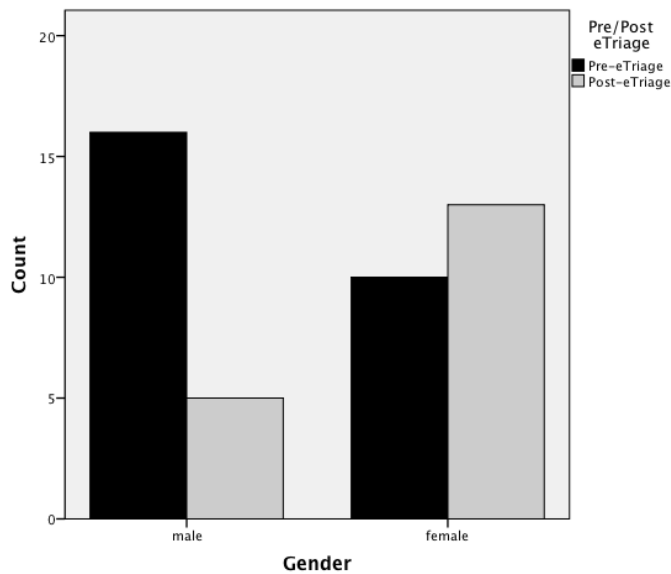
The following descriptive statistics summarise the main features of the neutropenic sepsis data using bar charts and allow a comparison between the pre and post eTriage cohorts for: age, gender, time of arrival, mode of arrival, laboratory established neutrophil count and early warning score.



$$\chi^2 = 2.723 \text{ } p < 0.438$$

Figure 5.18 Age ranges in the pre and post eTriage groups - neutropenic sepsis cohort

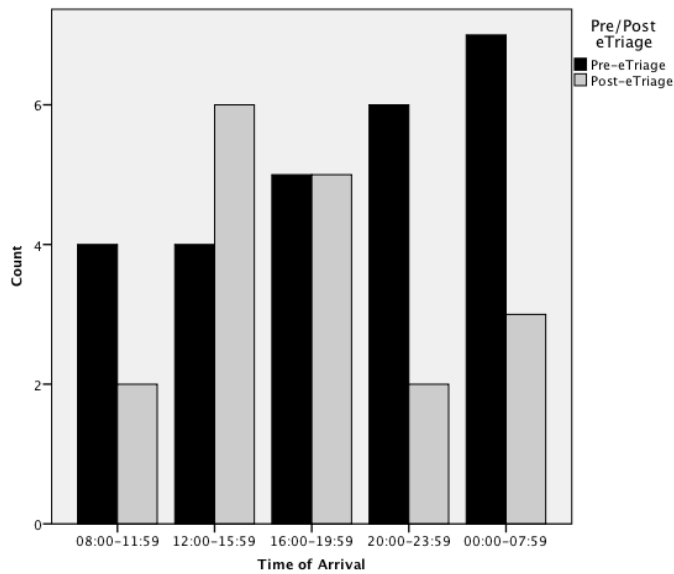
There was no statistically significant difference in the ages of patients in the pre and post eTriage groups.



$$\chi^2 = 3.600 \text{ } p < 0.058$$

Figure 5.19 Gender in the pre and post eTriage groups – neutropenic sepsis cohort

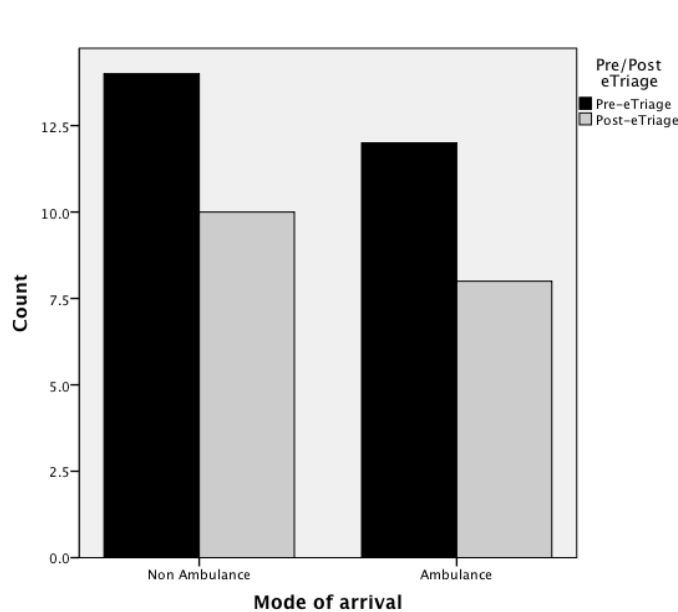
There was no statistically significant difference in the gender of patients in the pre and post eTriage groups.



$$\chi^2 = 3.322 \text{ } p < 0.505$$

**Figure 5.20 Time of arrival in the pre and post eTriage groups – neutropenic sepsis cohort**

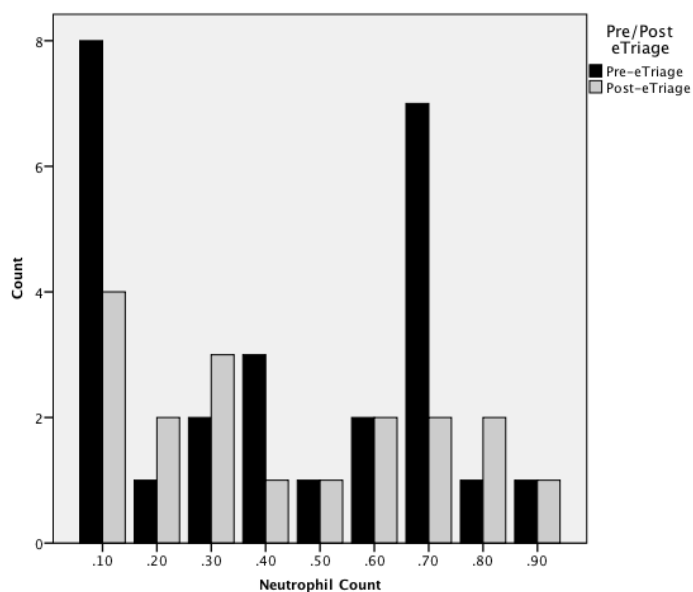
There was no statistically significant difference in the time of arrival of patients in the pre and post eTriage groups.



$$\chi^2 = 0.000 \text{ } p = 1$$

**Figure 5.21 Mode of arrival in the pre and post eTriage groups – neutropenic sepsis cohort**

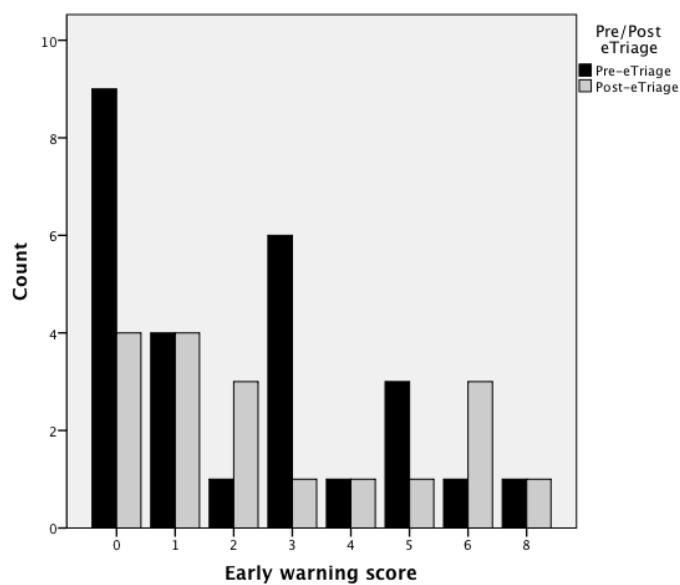
There was no statistically significant difference in the mode of arrival in the pre and post eTriage groups.



$$\chi^2 = 4.766 \text{ p} < 0.782$$

Figure 5.22 Neutrophil count in the pre and post eTriage groups – neutropenic sepsis cohort

There was no statistically significant difference in the neutrophil count in the pre and post eTriage groups.



$$\chi^2 = 7.281 \text{ p} < 0.400$$

Figure 5.23 Early warning score in the pre and post eTriage groups – neutropenic sepsis cohort

There was no statistically significant difference in the early warning scores in the pre and post eTriage groups.



### *5.7.2 Summary of the neutropenic sepsis descriptive statistics*

The above descriptive statistics have compared the pre and post eTriage neutropenic sepsis groups. When the neutropenic sepsis pre and post eTriage samples are compared there is no statistically significant difference in: age, gender, time of arrival, mode of arrival, laboratory established neutrophil count and early warning score. This demonstrates that all patient characteristics are similar.

### *5.7.3 Results of the inferential statistical analysis of the neutropenic sepsis data*

Inferential statistics have been used to assess the difference in the initial management patients that presented with neutropenic sepsis before and after the introduction of eTriage. As with the triage dataset the data is categorical/nominal, and once again Chi Square is used.

The following results compare the pre and post eTriage neutropenic sepsis cohort for the initial neutropenic sepsis management by assessing the following:

- a) Triage priority allocated “very urgent”
- b) Full blood count taken within one hour
- c) Timeliness of antibiotics

#### **Triage priority – very urgent**

Pre-eTriage 40% versus post eTriage 27.8%

$$\chi^2 = 0.255; p=0.61$$

There was no statistically significant difference between the pre and post eTriage groups. When eTriage was used there was no increased likelihood that patients would be triaged as a “very urgent” priority.

### **Full blood count taken within 1 hour**

Pre eTriage 69.2% versus post eTriage 75%

$$\chi^2 = 0.03; p=0.96$$

There was no statistically significant difference between the pre and post eTriage groups. When eTriage was used there was no increased likelihood that patients would have a full blood count within 1 hour of arrival.

### **Timeliness of antibiotics within 1 hour**

Pre eTriage 11.5% of patients had antibiotics within 1 hour versus 5.6% post eTriage

$$\chi^2=4.55; p=0.47$$

There was no statistically significant difference between the pre and post eTriage groups. When eTriage was used there was no increased likelihood that patients would receive antibiotics earlier.

#### *5.7.4 Summary of the results from the neutropenic sepsis dataset*

Although the pre and post eTriage samples were similar in the neutropenic sepsis data set there was no evidence that eAlerts within eTriage and the availability of the neutropenic guidelines immediately after triage altered care in any way. Due to the small sample size and negative results no further analysis was undertaken. The impact of these results and possible explanations will be addressed in the next chapter.

### **5.8 Summary**

This results chapter has presented the descriptive and inferential statistics for both the triage and neutropenic sepsis cohorts. Logistical regression was undertaken for the triage data to consider confounders and the underlying decision-making trends over time. The result of the primary outcome measure

was positive in that there was a statistically significant improvement in the quality and safety of triage decisions when eTriage was in use. With regard to the secondary outcome measure, the results did not demonstrate any significant improvement in the care of patients with neutropenic sepsis. The discussion chapter that follows will consider these findings and the new insights that they have unearthed.

## **CHAPTER 6: DISCUSSION**

### **6.1 Introduction**

This discussion chapter interprets, discusses and analyses the results of this study in light of the research question, aim and objectives and the outcome measures. The primary outcome measure sought to determine whether the safety and quality of triage decision-making was improved by the introduction of eTriage. The secondary outcome measure considered whether there were improvements to the process of care for patients who presented with neutropenic sepsis. The results of each of these outcome measures will be discussed in turn. There will be further analysis regarding the contribution of CCDSSs in EDs with regard to: quality and safety, clinical decision-making and safety and finally methods for evaluating CCDSSs in emergency care areas will be debated. The discussion will identify the contribution of this research for the development of CCDSSs in emergency care and for practitioners before concluding with a review of limitations.

### **6.2 Primary outcome measure**

The primary outcome measure assessed the safety and quality of the triage decision-making process. This was judged by establishing the following:

- a) The accuracy of the triage prioritisation process
- b) The assessment of pain
- c) The appropriate management of any pain identified at triage

Within this next section the results concerning the effectiveness of eTriage to support accurate prioritisation and the assessment and management of pain will be considered. With regard to the first primary outcome measure, this research considered: selection of the correct triage presentational flow chart, the selection of the correct discriminator and finally the allocation of the appropriate priority category. The effect that the intervention had on these three aspects will be discussed. The changes to the assessment and management of pain at triage will

then be analysed. eTriage demonstrated improvements in all these areas and the significance of this for the advancement of knowledge and for clinical practice will be highlighted. To begin this analysis consideration will be given to the pre and post intervention groups and their characteristics.

#### *6.2.1 Overview of the pre and post eTriage groups – triage cohort*

This study used an ITS design to analyse the impact of a CCDSS on triage decision-making before and after its introduction. An important consideration when analysing the generalisability of the results is to consider the homogeneity of the pre and post intervention groups (Davis & Scott, 2007). The retrospective random sampling approach was undertaken to ensure that the pre and post intervention groups were similar in every way. In terms of their basic characteristics: age, gender, time of arrival, mode of arrival, triage priority and stream there was no statistically significant difference between the pre and post eTriage groups. This provides evidence that there were no individual confounding variables that may have impacted on the triage decisions: the groups were equal. The similarity in the cohorts allows some degree of confidence in the initial results that compared the two groups. However, when the experience of the triage nurses was analysed there was a difference between the pre and post eTriage groups. There was a significantly larger number of triage nurses with <3years experience in the post eTriage group ( $p<0.001$ ). This factor was analysed as part of the logistic regression model to consider if experience had a relationship with decision-making. The results of the logistic regression demonstrated that experience was not a confounding variable; this will be discussed in more detail in later sections.

The final consideration of the sample is regarding its representativeness. The questions to consider of any sample is whether the sample is representative of the target sample (i.e. all EDs attendances) and ultimately whether it is representative of a broader population (Polit & Beck, 2008). However, this research is only concerned with the impact of a bespoke CCDSS in one ED. The critical question for this research is whether this sample is representative of the total attendances during the time periods and therefore can inferences be drawn

to the whole population (Bruce et al., 2008). To give absolute assurances about representativeness a review of the whole population (from the hospital database) could have taken place to establish if: the pre intervention sample (n=400) was representative of the total population at the time (likely to be >80,000) and the post intervention sample (n=400) was also representative of the total population at the time (likely to be >85,000). However, this has not been done as the selection of a random sample using nQuery Adviser 7.0 serves to obviate bias and is therefore representative. Section 6.8 & 6.9 discusses the limitations of the research and the effects of other possible confounding variables that have been identified in the literature. The next section analyses the first primary outcome measure concerning the triage prioritisation process.

#### *6.2.2 The impact of eTriage on the triage prioritisation process*

The results of this research identified a statistically significant improvement in the triage nurse's decision-making following the introduction of eTriage. This was the first primary outcome measure and was concerned with eTriage's ability to improve quality and safety of the triage processes. There are three stages of triage decision-making required when using the MTS, see Figure 2.3 (Mackway-Jones et al., 2006)

1. Problem identification
2. Information gathering and analysis (history taking +/- examination)
3. Identification of the most significant clinical feature

In this research two of these stages have been directly measured before and after the introduction of eTriage. 1<sup>st</sup> Stage: *Problem identification* was measured by judging if the triage nurse has selected the correct MTS presentational flowchart. 3<sup>rd</sup> Stage: *Identification of the most significant clinical feature* was measured by judging if the triage nurse had selected an appropriate discriminator (See Appendices 1 & 2 for flow chart examples). Within MTS the selection of the correct discriminator automatically leads to the allocation of the appropriate clinical priority: immediate, very urgent, urgent, standard and non urgent. Prior to

eTriage correctly linking every discriminator with the assigned clinical priority would mean referring to the flow chart on every occasion. This is highly unlikely to consistently happen in practice so unless all the triage nurses had been able to memorise each of the 50 presentational flowcharts, this final step in the triage process may also be at risk of inaccuracies. It has previously been identified that relying on memory, coupled with time pressures at triage can lead to flawed decision-making (Dong et al., 2005). Therefore the final element to be measured in triage decision-making process in this study was if the correct clinical priority category for the patient had been assigned. Another way to consider the triage process and what was measured in this research is:

1. Patient presentation
  - a. selection of the correct presentational flowchart.
2. Discriminator
  - a. selection of an appropriate discriminator.
3. Decision
  - a. allocation of an appropriate triage category.

These results will be analysed in turn together with a discussion of their impact.

#### *6.2.3 The effect of eTriage on the selection of the correct triage chart*

The first stage of the triage process is to identify the patient's main problem and when using the MTS this translates to selecting an appropriate presentational flow chart (Mackway-Jones et al., 2006). Before the introduction of eTriage the correct triage chart selection was 79.8%, post intervention this rose to 94.8% and was highly statistically significant ( $p < 0.001$ ). Logistic regression was planned for this data but was not mathematically possible as the post intervention percentages were near to 100. Although it was not possible to consider the effect of: age, gender, mode of arrival and triage nurse experience on the selection of the right triage chart the observed rates (as opposed to the fitted rates) were calculated to expose the underlying trend (Figure 5.15). There is a slight upward

trend pre eTriage and a very slight downward trend post eTriage. However it's important to note that the post eTriage rate nears 100%. When large effect sizes are noted in B&A studies it can provide convincing evidence of the effect of the intervention (Brown & Lilford, 2008).

A known confounder considered in previous CCDSS research is the experience of the clinician (Kwok et al., 2009; Britton et al., 2013). It was not possible to use logistic regression to consider the impact of triage nurse experience on the selection of the correct chart. However, because there was a statistically significant difference between the experience of the triage nurses in the pre and post intervention cohorts further analysis was undertaken. Table 5.13 considered the effect on triage nurse experience (less experienced versus experienced) on selection of the right chart. The baseline for both the inexperienced and experienced triage nurses (78.6% vs 82.7%) is similar and the improvement post intervention is also similar (82.7% vs 96.5%). However the logistic regression that has analysed the effect of triage nurse experience provides more robust evidence and is discussed in a later section

#### *6.2.4 The effect of eTriage on the selection of an appropriate discriminator*

The selection of the correct discriminator is the 3<sup>rd</sup> and final stage in the MTS system process as described above in section 6.2.3 (Mackway-Jones et al., (2006). It involves identifying the most important/significant sign or symptom in the patient's presentation. Within MTS selecting a discriminator automatically leads to the allocation of its corresponding priority category. For example selecting cardiac chest pain corresponds with a very urgent triage category. The challenge when using a manual triage system is remembering the prioritisation process accurately (Dong et al., 2005). Discriminator selection and allocation of the corresponding triage category are both measured in this study. There was a statistically significant improvement in the selection of the correct discriminator post intervention ( $p < 0.001$ ). The observed pre-eTriage correct discriminator rate was 55.2% compared with a post eTriage rate of 81.5%.



#### *6.2.5 The effect of eTriage on the allocation of the correct clinical priority*

The ultimate decision that a triage nurse has to make is the allocation of an appropriate clinical priority for the patient (FitzGerald et al., 2010). This ensures the safety of the patient as a decision is made about those that are clinically at risk of waiting and those that are not (Considine, Ung , & Thomas, 2001; van der Wulp et al., 2008). Triage decisions are the foundation of patient assessment in emergency care upon which subsequent care is initiated (Considine et al., 2001). This study demonstrates a positive change in the accuracy of the final triage decision, the allocation of the clinical priority ( $p < 0.001$ ). The observed pre-eTriage correct priority rate was 60.5% compared with a post eTriage rate of 85.2%. This is a unique finding and has not been previously identified within the literature. The improvement in prioritisation accuracy with eTriage is a highly significant finding that has not been demonstrated before.

#### *6.2.6 Introduction: Logistic regression analysis*

The use of logistic regression in this study had two principle objectives. 1) to expose the underlying trend in decision-making 2) to explore the relationship between the intervention and other possible confounding factors such as: age, gender, mode of arrival, triage nurse experience and time period. This is consistent with the approach used by Buising et al. (2008) in their ITS study of antibiotic prescribing in an ED using a CCDSS. Logistic regression analysis was only undertaken for: correct discriminator and correct priority as it was not statistically possible to undertake regression analysis on any of the other data. The underlying trend for correct discriminator and correct priority are considered in turn. The logistic regression for confounding variables is discussed in section 6.2.9

#### *6.2.7 Logistic regression analysis: the underlying trend for the selection of the correct discriminator*

The fitted time trends for correct discriminator selection (Figure 5.13) show no statistical evidence of any trend in the pre eTriage period. Although there appears to be slight increase in the pre eTriage time period the range within the pre

intervention period for correct discriminator is only 52.8%-58.5%. At 24 months, one-year post eTriage there is a much greater correct discriminator percentage than would be expected from the pre eTriage period. The expected correct discriminator effect is 67.6% vs the fitted 86.7%. This significant increase in the selection of the correct discriminator when the characteristics of the whole cohort have been standardised does provide convincing evidence of the effect of eTriage on this element of triage decision-making.

#### *6.2.8 Logistic regression analysis: the underlying trend for the allocation of the correct clinical priority*

Logistic regression was used to expose the underlying decision-making trend and enable the impact of eTriage to be uncovered. The fitted time trends for correct priority (Figure 5.14) show no evidence of any trend over time in the pre eTriage period. There is evidence in the literature that practice does improve over time and that this can make it difficult to detect the true effect of an intervention (Buisson et al., 2008). From the analysis within this research it appears that the accuracy of triage decision-making during the year pre eTriage is fairly static. This observation is of great interest for several reasons. Firstly, it does not support the suggestions in the literature that behaviour changes over time, the use of an ITS design is advocated for this reason (Grimshaw, J et al., 2000; Robson et al., 2001). Secondly, if an ITS approach had not been used and a single measure taken at any one of the time points there would have been less confidence in the post intervention effect due to the significant threat of regression to the mean (Barnett et al., 2005). The multiple time points used in an ITS study are known to make it easier to control for confounding variables and regression to the mean (Harris et al., 2006). If a one off measurement had been taken before the intervention there would be no way of knowing if this relatively low fitted score (60.1%) was in fact a spurious result influenced by confounders.

One year after the introduction of eTriage there is a much greater mean probability of the allocation of the correct priority (86.3% fitted). Because there is no underlying pre intervention trend there can be a degree of confidence that this

result was due to the effect of the intervention. A slight decline in this improved trend is noted but is not statistically significant ( $p < 0.354$ ). A statistical strength of this study is that it goes beyond a before and after analysis. Of the ITS designs identified in the literature review (Day et al., 1995; Schriger et al., 1997; Schriger et al., 2000; Buising et al., 2008; Gibbs et al., 2012) only one analysed the underlying secular trend (Buising et al., 2008). The other studies did not capture data at multiple time points. EPOC (2013b) state that data should be collected at a least three time points before and after the intervention to enable suitable analysis. The next section will discuss the effect of confounding variables analysed as part of the logistic regression.

#### *6.2.9 Logistic regression analysis of confounding variables*

This initial analysis considered the accuracy of the triage prioritisation process and compared the pre and post intervention groups in the same way as a B&A study would compare the pre and post intervention results. The predominant research design in the literature review was B&A studies (Asaro et al., 2006; Goergen et al., 2006; Jadav et al., 2009; Kwok et al., 2009; Niemi et al., 2009; Melnick et al., 2010; Carman et al., 2011; Drescher et al., 2011; Nelson, J et al., 2011; Raja et al., 2012; Bond et al., 2013; Britton et al., 2013; Jones, B. et al., 2013). In general CCDSS research the B&A design is also the design most often used (Liu & Wyatt, 2011). As previously identified within the literature review there are numerous threats to validity with a pre and post intervention design. Within the literature review only 40% ( $n=9$ ) of studies considered confounding variables and included them in their analysis (Schriger et al., 2000; Buising et al., 2008; Kwok et al., 2009; Melnick et al., 2010; Carman et al., 2011; Britton et al., 2013; Dexheimer et al., 2013; Jones, B. et al., 2013). Gender, age, disease severity and clinician experience were the most common confounders that were addressed. A significant strength of this research is that it goes beyond a simple comparison of pre and post intervention groups and considers the underlying secular trend and confounding variables using regression analysis.

The regression analysis that considers the confounding variables for correct discriminator and correct priority revealed similar results (Table 5.11 & 5.12). They both revealed that two of the variables: the mode of arrival and the intervention had an independent effect on the correct clinical priority being allocated. These two variables are both factors that influence whether the correct discriminator and or the correct priority is assigned and will be considered in turn in the next sections.

#### *6.2.10 Mode of arrival as an influencing factor in triage decision-making*

Mode of arrival has been identified as having a statistically significant relationship with both discriminator selection ( $p < 0.001$ ) and correct prioritisation ( $p < 0.001$ ) when all other patient variables were controlled for. With regard to the selection of the correct discriminator the odds ratio (OR) is 2.34 meaning that the odds of the correct discriminator being selected is 2.34 times higher if the patient does not arrive by ambulance [95% CI 1.57-3.48]. When the regression analysis considers the selection of the correct priority the OR is 1.96 meaning that the odds of a correct priority being assigned is 1.96 times higher if the patient does not arrive by ambulance [95% CI 1.29-2.96].

Mode of arrival was classified as ambulance or non-ambulance (car, bus, taxi, bicycle, on-foot etc.) and is associated with an increase in correct triage prioritisation when all the other variables in the model are controlled for. The direction of the relationship in the logistic regression for mode of arrival indicates that there is a positive association when patients don't arrive by ambulance.

It could be assumed that patients who arrive by ambulance are the group associated with improved triage prioritisation as they have already had a comprehensive pre-hospital assessment, this is then handed over to ED staff (Blaber, 2012). However, the results of this research do not support that understandable assumption. In this research increased accuracy of triage prioritisation is seen more often in those patients that do not arrive by ambulance. There are possible explanations for this from the literature and from the researchers understanding of the practice environment. Talbot & Bleetman

(2007) suggest that ED staff are often distracted from listening to the ambulance handover as they begin making their own assessment. This appears to be more of an issue if the patient is critically ill and the ability to focus of the verbal handover may be compromised further (Talbot & Bleetman, 2007; Carter, Davis, Evan , & Cone, 2009; Evans et al., 2010). The type of patient that arrives by ambulance is different when compared to those that arrive by any other means. In general terms those arriving by ambulance are likely to have immediate healthcare needs and are more likely to be streamed into the majors area of a department. Currently there is no national definition of what constitutes a “majors” patient but arriving by ambulance is used as a proxy measure by the DH (2010a). A brief review of the research data supports this; 75% of patients who arrived by ambulance and only 35% of non-ambulance arrivals were streamed to majors.

Factors thought to affect the quality of handovers in healthcare have been identified as: frequent distractions, poor handover structure and lack of training in handovers (Sujan et al., 2013). There is evidence that when care is handed over from an ambulance crew to ED staff there are inaccuracies in documentation (Redfern, Brown , & Vincent, 2009; Murray, Crouch , & Ainsworth-Smith, 2012). Ineffectual handovers between the ambulance service and ED staff risk compromising patient quality and safety (Murray et al., 2011) and this is evident in these results as correct prioritisation is more likely for patients who don’t arrive by ambulance. The literature suggests that there are features within the handover: how it is delivered and how it is received that could affect decision-making.

The triage procedures in place during the course of the study may have had an unknown effect on triage accuracy. In the department in this study there are two triage points, one for patients that arrive by ambulance and one for those who arrive by any other means. The operational processes for the triaging of patients that arrived by ambulance and those that “walked-in” were different and changed in 2011. The volume and type of patient (major or minor) through these two triage points is different and could contribute to the differences in accurate prioritisation. Thirty percent of patients arrive by ambulance (Table 5.7) but 75%

of these are streamed to majors. In the pre intervention period the Nurse-in-Charge of the department triaged patients arriving by ambulance, (see Table 4.1); this was as well as his/her shift leader responsibilities. Changes in DH performance targets in 2010 increased the emphasis on the initial assessment (triage) of patients arriving by ambulance and contributed to a change in processes in EDs across the UK (DH, 2010a). From 2011 EDs in the UK had a new clinical quality indicator to achieve with regard to the initial assessment of patients arriving by ambulance; this had to be achieved within 15 minutes. The department in this study changed its triage processes and an RN trained in triage had the specific role of assessing all patients that arrived by ambulance within the 15 min target. They had no other responsibilities. Although the experience of the triage nurse has not been shown to be an influencing factor in correct prioritisation (see section 6.2.12) there may be other unknown features of the triaging process that account for the observed difference; these warrant further future investigation.

#### *6.2.11 eTriage as the major influencing factor on triage decision-making*

Taking into account mode of arrival as an influencing factor the strongest predictor in the regression model for the selection of the correct discriminator ( $p < 0.004$ ) and the allocation of the correct clinical priority ( $p < 0.034$ ) was the intervention. With regard to the selection of the correct discriminator the OR is 29.76 meaning that the odds of the correct discriminator being selected is 29.76 times higher if eTriage is used [95% CI 2.96-300.79]. When the regression analysis considers the selection of the correct priority the OR is 14.49 meaning that the odds of a correct priority being assigned is 14.49 times higher if eTriage is used [95% CI 1.27-172.22].

Both of these results have very large confidence intervals, due to the large parameter estimate and the large standard error. This was as a result of the design of the study. No data was captured for 1-year post intervention to allow the novelty of the system and any initial operational or implementation issues to settle. Because of this there were statistical difficulties in locating the intervention

effect within the data due to the sudden difference in results between months 9 and 24. Despite this issue this result clearly demonstrates that the most significant influencing factor on the triage nurses' decision-making ability was the use of eTriage. This is an important finding; it addresses the first part of the primary outcome measure and strongly suggests the positive impact of eTriage on departmental quality and safety.

The potential for CCDSSs to have a positive effect at triage has been previously described (Funderburke, 2008). However, there is only one study in the literature review that investigates computer decision-support at triage (Dong et al., 2005). Traditional "memory-based" triage is compared with a web-based tool on the same patients, these triage decisions were then reviewed by an expert panel (Dong et al., 2005). The results of the study by Dong et al., (2005) identify that the triage category identified by the expert panel was more closely aligned with the web-based tool than "memory-based" triage. These results suggest that when a decision-support tool is used the allocation of the correct clinical priority increases.

However, the prospective observational design used in the study may have actually introduced a threat to the validity of the study. The research nurse triaged the patient again some time after the initial (memory-based) triage took place. Although blinded to the initial triage category there are other factors that could clearly effect this second decision. The research nurses were not subject to any of the time pressures or competing demands of the triage nurse. The research nurse followed the patients and assessed them using the web-based tool in the clinical area they had been allocated to following their triage assessment. Whilst they were not privy to the initial triage category they could have been influenced in their decision-making when assessing patients in a resuscitation room versus a waiting room. Despite this limitation the research took place in an ED and did not test the decision-support on simulated patients, as can be the case in triage research (Gerdtz, M. & Bucknall, 2007; Wolf, 2010). Due to the prospective nature of the study it would not have been subject to the effects of

historical changes as is often the case with B&A designs (Harris et al., 2006; Liu & Wyatt, 2011).

When B&A studies are conducted over a period of time the influence of other factors e.g. teaching, training can contribute to changes in patient management. Asaro et al., (2006) and Drescher et al., (2011) both comment on the launch of the clinical guideline that was part of the CCDSS through teaching sessions and departmental posters. Regarding these issues a strength of the research in this thesis was the use of an ITS design together with the random sampling approach used for each time series month.

This research has demonstrated that when eTriage was used there was a statistically significant increase in the accurate selection of the: triage chart, MTS discriminator and clinical priority. In clinical practice the impact of selecting an appropriate triage chart means that the likelihood of overall triage accuracy is increased. The clinical decision-making of the triage nurse has been improved with eTriage. The identification of the most significant clinical feature of the patient's presentation (represented by the discriminator) increased significantly. With eTriage the triage nurse made more accurate decisions with regard to this step in the triage process. Although the allocation of the correct clinical priority also improved significantly this was a function of eTriage rather than triage nurse improved decision-making. This element of the triage process was not a decision the triage nurse made but a functional element of the system; it was automatically allocated based on which discriminator was selected. Although it is important to make this distinction it does not diminish the fact that clinical safety was improved by more accurate triage prioritisation. The final area for consideration within the triage decision-making process is the experience of the triage nurse

#### *6.2.12 Triage nurse experience*

Experience of the triage nurse is of particular relevance to this research for several reasons. Firstly, the post eTriage cohort had a significantly higher number of less experienced triage nurses. Secondly, despite these obvious differences



between the pre and post intervention groups the regression analysis did not reveal that triage nurse experience had any influence over decisions made during triage. Finally, part of the rationale for the development of a triage CCDSS was to support the inexperienced clinician. In this research the experience of the triage nurse does not contribute to the accuracy of the triage prioritisation when eTriage is used. This is a highly significant finding for CCDSS research and clinical practice.

Evidence from the literature regarding the training and experience of triage nurses and its impact on decision-making is conflicting. Considine et al., (2001) administered a questionnaire to 31 emergency nurses which contained 10 patient scenarios with the aim of identifying if triage priority was affected by type and length of nursing experience. The length of experience as either an emergency nurse or a triage nurse was reviewed and there was no correlation with accurate triage decisions (Considine et al., 2001). Interestingly overall levels of agreement were low and only 58% of the triage decisions were viewed as accurate. A more recent Swedish study demonstrated similar levels of agreement with paper-based triage scenarios (Göransson, Ehrenberg, Marklund, & Ehnfors, 2006). However this study did identify a positive correlation between both general nursing experience and emergency nursing experience and the ability to make effective triage decisions (Göransson et al., 2006).

In a comprehensive study of triage practices in a Canadian paediatric ED Patel, Gutnik, Karlin & Pusic (2008) identified that less experienced nurses relied more heavily on guidelines when making triage decisions. Experienced triage nurses used previous experience and intuition based on a prior knowledge of guidelines when making triage decisions. For the experienced nurse, decision-making appeared to be at risk of inaccuracies when triage guidelines change. Patel et al. (2008) propose four areas for consideration with regard to triage decision making, they are: nurse factors, guidelines, patient factors and contextual factors. A subsequent study by Gerdtz, M. et al., (2009) based on the above framework by Patel et al., (2008) identified that the only nurse characteristic that was related to triage decision-making was the age of the nurse. The results of these studies are

contradictory regarding the role of experience and accuracy at triage. The study by Göransson et al., (2006) did identify an association, others have not (Considine et al., 2001; Considine, Botti , & Thomas, 2007; Gerdzt, M. et al., 2009).

The research in this thesis did not seek to understand how triage nurses make decisions or what nurse characteristics contribute to accurate decisions. It could be suggested that the results of the research in this thesis supports the findings that experience is not associated with accurate triage decisions (Considine et al., 2001; Considine et al., 2007; Gerdzt, M. et al., 2009). However this study sought to identify if emergency nursing experience bore any relationship to the accuracy of triage decisions when a CCDSS was used. Comparisons with studies using paper-based triage scenarios are likely to be unhelpful. Other research has explored the relationship nurses experience and the use of CCDSSs in different settings (Dowding et al., 2009a; Dowding et al., 2009b). These studies identify that less experienced nurses rely more heavily on decision-support. Those with more experience reported being likely to utilise it in unfamiliar situations (Dowding et al., 2009a; Dowding et al., 2009b). Experienced nurses have also been shown to manipulate CCDSSs to get the outcome they wanted (O'Cathain, Sampson, Munro, Thomas , & Nicholl, 2004).

The researcher's knowledge of the practice environment offers a further insight. In the department where this research took place, the experienced nurses predominantly had shift leadership responsibilities and therefore were likely to spend less time undertaking triage. Rather than years of experience, the regularity of triage practice may be more relevant to the debate about the impact of experience on triage decisions. Nevertheless, no other studies have looked specifically at whether a CCDSS at triage is affected by nurse experience. This research has demonstrated that eTriage improves triage accuracy regardless of triage nurses experience. This provides further support for its use in clinical practice and was part of the rationale for its introduction. The next section discusses the remaining elements of the primary outcome measure: pain assessment and pain management.

### *6.2.13 Impact of eTriage on pain assessment and management at triage*

The second part of the primary outcome measure was concerned with the assessment and management of pain. The impact of the intervention on these primary outcome measures is a significant finding within this study. Prior to the introduction of eTriage the overall observed percentage for pain scoring was 35% and after the introduction of eTriage it rose to 97.8%. This change was highly statistically significant ( $p < 0.001$ ). It was not possible to perform logistic regression modelling for this data due to almost 100% accuracy post intervention. However the observed percentages for each month were calculated to expose the underlying trend in pain scoring (Figure 5.16). There is some variation in pain scoring pre intervention but the trend never reached more than 41%. There is a significant, almost near perfect improvement in pain scoring post intervention.

This is a very important positive improvement as making an accurate assessment of pain is the cornerstone to appropriate pain management in emergency care (CEM, 2010b, 2010c). Patients value pain management highly when attending an ED and reducing pain levels is associated with improved patient experience (Graham, J., 2002; Bhakta & Marco, 2014).

The only UK study in the CCDSS literature review investigated the effect of mandatory pain scoring on analgesia provision for children attending an ED (Jadav et al., 2009). It found that although pain-scoring rates improved from 74% to 97%, this did not translate to an increase in analgesia administration. The final element of the primary outcome measure considered this aspect; following pain scoring was appropriate analgesia administered?

The pragmatic decisions that were made regarding the coding of the data for pain assessment and pain scoring may have had an impact on the results. Patients were coded (yes) as having a pain score if this was recorded within the triage record (score of 0-10, see Appendix 3). Some presentations e.g. mental illness are not likely to present with pain. This was not encountered within the pilot and therefore a decision was made during data collection regarding the coding of this data in the pre intervention cohort. If pain was not recorded as zero for these

presentations they were still coded as if they had a pain score (yes). This decision was made rather than code them as missing as pain scoring for these patients was not applicable. Another interesting discovery were a number of patients who had received some pain relief at triage but did not have a pain score. This was identified during the pilot and full data collection process. Clearly the patient had had some form of pain assessment, to be given analgesia. However the critical judgement to be made was whether the analgesia was appropriate. Without a pain score the appropriateness of analgesia could not be decided; pain score and appropriate analgesia are intrinsically linked. For those records where analgesia was administered but there was no pain score, appropriateness was coded as “no”. This study has not been able to reveal the accuracy of any pain assessment if it had not been recorded.

Prior to the introduction of eTriage the overall observed percentage for the administration of analgesia according to the patient’s pain score was 26.2% and after the introduction of eTriage it rose to 78.5%. This change was highly statistically significant ( $p < 0.001$ ). It was not possible to perform logistic regression modelling for this data due to the high levels of accuracy post intervention. However the observed percentages for each month were calculated to expose the underlying trend in analgesia administration (Figure 5.17). There is some variation in the pre intervention percentages for appropriate analgesia administration (range 19-33%). However the increase at month 24 is significant, although again there is variation (range 73%-83%), which is slightly wider. These results are in contrast to the findings of Jadav et al. (2009). In the research reported in this thesis there is an association between the introduction of eTriage, pain scoring and then the administration of pain relief that is appropriate to the patient’s score. This is a significant finding in terms of improving the quality of care for ED patients and also demonstrates the ability of eTriage to do this.

A similar improvement was noted by Fosnocht & Swanson (2007) when they introduced a pain management protocol at triage. Prior to the introduction of the protocol 45% of patients presenting with musculoskeletal extremity or back pain received analgesia. Following training and the introduction of the pain

management protocol this increased to 70%. However the introduction of the pain protocol, the associated training and the research study itself are likely to have contributed to a “Hawthorne effect” (Robson et al., 2001). The B&A design used by the researchers is at risk of regression to the mean and does not permit any analysis of the sustainability of the protocol (England, 2005).

A strength of this eTriage research is that it clearly demonstrates a sustained improvement in pain management. When US ED nurses were interviewed about perceived barriers to pain assessment they described feeling “overwhelmed” with the volume of patients waiting for assessment and the demands on their time when the ED was overcrowded (Bergman, 2012). Hwang, Harris, Morrison & Richardson (2006) identified that overcrowding contributed to delays in the assessment and management of pain in ED. A multi-centre study covering 20 US and Canadian EDs demonstrated that all sites, regardless of their triage systems showed excessively long waits for pain management (Ducharme et al., 2008). They identified a clear link between waiting time and pain management. Ducharme et al., (2008) suggest that the constraints within an ED environment require some very specific strategies to improve pain management. In an Australian study of pain management practices in EDs it was noted that when nurses administered analgesia following a protocol patients experienced less delays (Fry, Bennetts , & Huckson, 2011). However inconsistencies in pain scoring were noted and contributed to poor pain management. Delays in the administration of analgesia have also been noted in a UK study (Brennan, Carr , & Cousin, 2007).

Any approach taken to improve the quality of care for ED patients needs to take account the challenges of the clinical environment. eTriage was developed as a means of mitigating against increasing demand and the inexperience of staff. Pain assessment and management was selected as measure of the impact of eTriage. Pain is a common presentation and there are consistent reports in the literature that its management is still suboptimal. The use of the CCDSS eTriage has had a positive effect on pain scoring and the appropriateness of analgesia given.

#### *6.2.14 Primary outcome measure – summary*

The results of the primary outcome measures indicate that the introduction of the CCDSSs eTriage has important benefits. The safety of patients in ED was improved as there was a significant increase in correct prioritisation over and above the underlying trend. The quality of care for patients attending with pain was also consistently improved in the post intervention period over and above the underlying trend. These results have demonstrated the positive effects of a CCDSS system in an ED that were sustained when measured up to two years after introduction. The wider impact of these results in supporting clinical decision-making and to improve quality and safety in EDs will be discussed later in this chapter.

### **6.3 Secondary outcome measure**

The secondary outcome measure was concerned with patient safety and assessed the management of patients that presented with possible neutropenic sepsis. Appropriate management was judged by assessing the following

- a. Triage priority allocated as “very urgent”
- b. Full blood count taken within one hour
- c. Timeliness of antibiotics

Within this next section the results concerning the effectiveness of eTriage to improve the safety and process of care for patients presenting to ED with possible neutropenic sepsis will be discussed. eAlerts within eTriage directed the triage nurse to allocate a high clinical priority for the patient if neutropenic sepsis was a possibility (See Figures 2.15 & 2.16). A further prompt was to inform the “nurse-in-charge” so that he/she could expedite pathological investigations, namely an FBC and prompt medical assessment. At the end of the eTriage assessment the pathway for the management of potential neutropenic sepsis was automatically printed and accompanied the patient’s ED clinical record to be used by the doctor (See Appendix 4). eTriage did not show any statistically significant benefits for

patients who presented with possible neutropenic sepsis, possible explanations for this will be discussed. To begin this analysis consideration will be given to the pre and post intervention groups and their characteristics.

#### *6.3.1 Overview of the pre and post eTriage groups – neutropenic sepsis cohort*

A retrospective sampling approach was used to identify all the patients during the two study periods (pre intervention April 2009-March 2010 and post intervention April 2011-March 2012) that presented with neutropenic sepsis. Data was extracted from the hospital's haematology database and included all patients that had a FBC requested by the ED and the neutrophil count was  $<1.0$ . The sample sizes were very small and therefore the data from the whole pre and post intervention was analysed (pre  $n=26$ , post  $n=18$ ).

It is important to recognise that this would not have been the total number of patients presenting to the ED during the two time periods with "possible" neutropenic sepsis. The only way to collect any data retrospectively was to identify those who were neutropenic (neutrophils  $< 1.0$ ). Only a prospective study could have captured all "unwell" patients presenting to ED on chemotherapy who were suspected of being neutropenic.

The descriptive statistics presented in section 5.7.1 identify that there was no statistically significant difference in: age, gender, time of arrival, mode of arrival, neutrophil count and early warning score (EWS) between the groups. EWS was measured as a means of identifying those critically ill from sepsis and the possible effect that this may have had on the improving times to treatment. However the EWS of the pre and post intervention groups were similar. The similarity of the groups can give some confidence that any confounding variables have been evenly spread. Clinician experience was not recorded in this dataset as there would have been a minimum of three members of staff involved in the decision-making process: triage nurse, nurse-in-charge and doctor. It would not have been possible to identify any confounding effect from 3 members of staff with such a small overall cohort.

### *6.3.2 Impact of eTriage on the process of care for patients with potential neutropenic sepsis*

eTriage did not demonstrate any statistically significant benefits in terms of improving the safety of patients with potential neutropenic sepsis by improving the timeliness of their care. There was no difference in: the allocation of a “very urgent” triage priority, the timeliness of an FBC sample being taken or the administration of antibiotics within one hour. Neutropenic sepsis was selected as a presentation where safety elements can be measured and there is significant mortality and morbidity associated with delays in initial care and treatment (Mort et al., 2008). It was felt that eTriage could provide the necessary prompts to the clinicians involved to highlight what had to be done as part of their initial assessment. CCDSSs can create a unique opportunity to further support clinicians in the management of rare but potentially life threatening conditions (Holroyd, Bullard, Graham , & Rowe, 2007). By standardising care they can ensure that the essential elements in management are delivered; for example a high clinical priority, an immediate FBC and timely antibiotics. Some possible explanations for these results follows.

Firstly the way that eTriage was structured with eAlerts and the printing of a paper copy of the clinical guideline may not have been appropriate. The researcher was involved in the development of eTriage and instructed the developers on the clinical content of the system. However, usability testing of the system on groups of ED staff did not take place (and was not considered in this study). This has been regarded as an essential component of testing a system (Carroll, Anand , & Downs, 2012). Testing with staff may have identified design features that were flawed regarding the prompts for neutropenic sepsis.

There was only one study identified in the literature review that printed out a paper guideline. Dexheimer et al., (2013) encountered similar problems in a study of asthma management in a paediatric ED. In their study the printing of the paper-based guideline at the end of the triage episode did not alter clinician behaviour. When they reviewed the records of patients in the intervention group



the paper-based protocol was only in the notes of 18% of children. They suggest that the protocol could have been detached from the clinical notes and “lost” at several points in the ED journey (Dexheimer et al., 2013).

Within the eTriage study the clinical pathways/protocols were not routinely scanned so this element could not be measured. Interestingly Dexheimer et al., (2013) undertook a follow-up survey with staff to understand the issue with the paper-based protocol. The staff reported not knowing what to do with the protocol or seeing the protocol but not using it. The design features of a system appear to be critical to its success and cannot be under-estimated. Ensuring that a system is quick, efficient and fits into the users workflow are seen as essential elements (Bates et al., 2003).

Secondly it is likely that the small patient numbers analysed did not enable any meaningful statistical comparisons to be drawn. The total sample size was 44, it was not possible to increase it as there was no way of capturing all those who presented with potential neutropenic sepsis but had a neutrophil count of  $>1$ . A purported benefit of CCDSS is that they can support the decision-making of clinicians when faced with rare, high-risk conditions (Holroyd et al., 2007). However, eTriage in this instance was not able to demonstrate this benefit. Future research could consider increasing the number of these “high-risk” presentations and analysing several at once. Examples could be testicular torsion and ectopic pregnancy.

### *6.3.3 Secondary outcome measure – summary*

The potential for eTriage to remind and assist the triage nurse with critical decisions and patient management are evident at triage. However the wider impact of the system beyond triage was not demonstrated by the results from the secondary outcome measure. Possible explanations are the design of the system, the small sample size or both. Further research is warranted when system design features and sample size can be addressed. The next section within this chapter considers the wider issues of quality and safety in emergency care in light of the results from the study on eTriage.

## **6.4 The contribution of CCDSSs to quality and safety in emergency care**

The overall aim of this research was to test the assumption that a computerised decision-support system at the point of triage was an effective means of improving the quality and safety of clinical care in ED. The primary outcome measure, which addresses triage prioritisation and pain management, demonstrated a significant improvement than would not have been expected based on the pre intervention data. The logistic regression modelling identified that the strongest independent predictor for correct prioritisation was the intervention i.e. eTriage. However the pre and post intervention data for patients who attended with neutropenic sepsis showed no additional benefit from the use of eTriage.

### *6.4.1 CCDSSs contribution to quality and safety in health care*

Within the general CCDSS literature there is evidence that systems can contribute to improvements in quality and/or safety (Hunt, D. et al., 1998; Bates & Gawande, 2003; Chaudhry et al., 2006; Øvretveit, Scott, Rundall, Shortell, & Brommels, 2007; Graham, T. et al., 2008; Scott, 2009; Lau, Kuziemsky, Price, & Gardner, 2010; Vincent, 2010; Black et al., 2011; Handel et al., 2011; Restuccia, Cohen, Horwitt, & Schwartz, 2012). In a study of 401 US hospitals Restuccia et al., (2012) found that those with high levels of information technology had a statistically significant improvement in: mortality rates, patient satisfaction and quality improvement practices. They postulate that it is likely that organisations with established IT systems have improved communication mechanisms, clearer documentation, enhanced monitoring systems and robust error prevention processes (Restuccia et al., 2012). Bates & Gawande (2003) identify multiple ways that IT can positively impact on patients' safety by improving: information exchange, access to information, prescribing practices, patient monitoring and the provision of decision support. In a comprehensive systematic review of the impact of IT on quality and efficiency Chaudhry et al (2006) identified three main quality benefits of decision-support and EPRs they were: adherence to guidelines, increased patient monitoring and reducing drug errors. When all the possible

strategies for improving the quality and safety of health care were reviewed the use of CCDSSs are seen to have an emerging role (Scott, 2009).

#### *6.4.2 The contribution of this study to the informatics quality and safety debate*

However, when studies evaluating the use of CCDSS are subject to rigorous evaluation and critical appraisal their conclusions are less encouraging (Garg et al., 2005; Black et al., 2011; Sahota et al., 2011). In a systematic review of CCDSSs used in acute care Sahota et al., (2011) found that of the higher quality studies only 69% (9/13) showed improvement in the process of care and only 8% (1/13) demonstrated a positive impact on patient outcomes. Black et al., (2011) are highly critical of the lack of robust evidence on the effectiveness of eHealth interventions. They identified only weak evidence that CCDSSs improved decision-making and when it did the only area to impact on patient outcomes was prescribing (Black et al., 2011). A substantial review by the Agency for Healthcare Research and Quality drew similar conclusions (Lobach et al., 2012). They identified strong evidence for improvements in the process of care when CCDSSs were used but little evidence of a positive effect on patient outcomes or costs. When considering the quality and safety benefits of IT in emergency care Handel et al., (2011) also identify that the evidence is mixed. The critical appraisal of studies in the literature review of this thesis supports this position. The evidence was weak regarding the impact of the CCDSSs due to inherent risks of bias in study design and/or the ability to control for or address confounding variables.

The study of eTriage and its impact addresses some of these concerns. The results of this study demonstrates that eTriage did identify clear benefits for quality and safety by improving decision-making at triage. The use of an ITS design provides a way of investigating the impact of a CDSSS in a complex clinical environment that adds to the small body of high quality evidence. The next section considers the role of CCDSSs and safer decision-making.

## **6.5 The role of CCDSSs in supporting clinical decision-making and making care safer**

Errors are commonplace in health care and can be described as

*“the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim”*

Institute of Medicine (2000) p 26

The particular type of mistakes in clinical practice that a CCDSS could impact upon are associated with: reasoning errors, inadequate knowledge, data omissions and faulty verification (Graber et al., 2002). Time pressures and information overload are well documented in emergency care (Woloshynowych et al., 2006; International Federation for Emergency Medicine, 2012). The overwhelming amount of information that requires processing in any clinical speciality is beyond the limits of human memory (Vincent, 2010). Human decision-making is clearly fallible, 44,000 deaths per year are attributed to medical errors in US hospitals (Institute of Medicine, 2000). All these concerns suggest a role for decision support and computation in health care (Vincent, 2010).

### ***6.5.1 eTriage and the use of “prompts” to support safer decision-making***

These issues were also central to the evolution of eTriage. Prompts and eAlerts were built into eTriage to alert ED staff to undertake certain clinical interventions. This clinical risk management function would suggest when things should happen for certain patients and at certain times during their ED attendance.

Twelve of the CCDSSs within the literature review used prompts/alerts to guide patient management (Schriger et al., 1997; Schriger et al., 2000; Busing et al., 2008; Roukema et al., 2008; Kwok et al., 2009; Niemi et al., 2009; Roy et al., 2009; Carman et al., 2011; Drescher et al., 2011; Nelson, J et al., 2011; Lim et al., 2012; Raja et al., 2012). Prompts/alerts are a prominent feature within CCDSSs and have been shown to improve adherence to clinical standards in both primary and secondary care (Roshanov, P. et al., 2011a; Sahota et al., 2011). Within an ED

setting patients may be at high risk when assessed and/or treated by the inexperienced clinician (International Federation for Emergency Medicine, 2012). There is an increasing body of evidence that demonstrates a statistically significant number of hospital deaths during evenings and weekends and that this is directly linked to the reduced numbers of experienced medical staff on duty out-of-hours (Dr Foster Intelligence, n.d.). Those new or transient to the speciality, (as is the case with junior doctor training in the UK) would not be familiar with high-risk patient groups that present in low numbers (Wears et al., 2010). The inexperienced, whilst having theoretical knowledge would not always be alert to uncommon or atypical presentations in clinical practice whilst managing competing and sometimes conflicting demands in emergency care (Woloshynowych et al., 2006).

Using decision-support to improve and standardise the care of patients with potential neutropenic sepsis was chosen to illustrate a safety element of eTriage. Lack of timely care in ED and knowledge of treatment priorities had been shown to contribute to morbidity and mortality in this patient group (Mort et al., 2008). However, the results of the research in this thesis did not detect any significant difference in the process of care between the pre and post intervention groups. It is important to highlight this “non-effect”; although patients were more accurately prioritised with eTriage wider effects were not seen. IT is now seen to have a clear role to play in assisting clinicians with decisions (Bates & Gawande, 2003; Black et al., 2011). With the increasing complexity of health care it has been suggested that safety is unmanageable without a degree of decision-support (Bates & Gawande, 2003). There are perhaps statistical and operational reasons why the process of care for patients with neutropenic sepsis remained unchanged, those being the small sample size or the printing of a paper guideline. Various authors identify moderately strong evidence that the successful implementation of systems require complete integration with the clinician’s workflow (Bates et al., 2003; Lobach et al., 2012). From this it could be argued that the provision of a guideline (within the patient’s paper record) for the

clinician to refer to is not adequate integration. These contextual issues and the interaction between technology and staff in ED require further exploration.

#### *6.5.2 The interaction between technology and clinical decision-making*

The final area to consider in this section is the way that clinicians make decisions and the subsequent interaction with decision support. Although this thesis was not investigating clinical decision-making in emergency care an understanding of the clinician/decision-support interface will have implications for developers, clinicians and educators.

Decision-making in emergency care is complex and time pressured. Interruptions are common and often involve changing to complete another task (Westbrook et al., 2010). When time is pressured clinicians use rapid intuitive decision-making processes (Standing, 2008; Noon, 2014). These methods are adaptive and effective and described by triage nurses when making patient assessments (Cone & Murray, 2002; Edwards, 2007). Conversely analytical reasoning requires time for data gathering and more detailed, time-consuming consideration of the available options (Carnevali et al., 1984; Banning, 2008). More recent research has identified that the most effective decision-makers are aware of these distinct approaches and move between them (Kahneman, 2011). However, in order to do this successfully, flexibility, significant self-awareness (in terms of inherent biases) and a level of competency is required (International Federation for Emergency Medicine, 2012). The sustainability of this degree of decision-making in ED together with the inherent challenges of the clinical environment, some suggest make this style of decision-making unrealistic (International Federation for Emergency Medicine, 2012).

Vincent (2010) identifies a fundamental issue regarding the development of technology and its increasing use in clinical care. When should technology be used to support decision-making and when should human judgement be used? The evidence reviewed within this thesis would suggest that when decisions are complex, clinical presentations rare and/or time limited, decision support systems would be of benefit. As the use of IT undoubtedly increases and EPRs become

commonplace developers and clinicians must consider carefully their role and function in clinical practice. Educators will also need to consider the role of decision-support when training the next generation of clinicians. Understanding the interaction between decision-making and technology will be critical. Vincent (2010) urges caution on an over-reliance with technology and a clear understanding of what information support systems can and can not do. The next section within this chapter revisits the earlier methodological discussions when evaluating CCDSSs and offers further insights as a result of investigating the effects of eTriage.

## **6.6 Methods of evaluating CCDSSs in health care**

There has been an extraordinary increase in the number of studies reporting on CCDSSs. When a 2005 seminal systematic review of trials that evaluated the effects of computerised CCDSS was undertaken 3,997 studies were screened (Garg et al., 2005). When this review was updated only five years later 12,493 citations were screened (Haynes & Wilczynski, 2010). This is testament to the growing interest in CCDSS and the volume of research this field is generating. Studies evaluating the use of CDSSs in acute care have demonstrated improvements in the process of care for patients (Hemens et al., 2011; Nieuwlaat et al., 2011; Roshanov, P. et al., 2011a; Roshanov, P. et al., 2011b; Sahota et al., 2011; Souza et al., 2011). But fewer studies have investigated the effects on patient outcomes and there is less evidence that these are improved (Black et al., 2011; Sahota et al., 2011; Lobach et al., 2012).

Methods for evaluating CCDSSs are varied; the predominant design identified in multiple reviews is quasi-experimental (Hunt, D. et al., 1998; Kaplan, 2001; Garg et al., 2005; Sanders & Aronsky, 2006; Black et al., 2011; Lobach et al., 2012). There is criticism within the literature regarding the use of non-experimental designs (Haynes & Wilczynski, 2010; Black et al., 2011; Liu & Wyatt, 2011). Those supporters of RCTs in health informatics research state that the evaluation of CCDSSs should be as rigorous as trials for new drugs (Haynes & Wilczynski, 2010). However, there is also recognition that RCTs are difficult to implement in clinical

settings and challenging to measure the impact of a complex intervention like a CCDSS (Aronsky et al., 2001; Chuang et al., 2002; Harris et al., 2006; Shcherbatykh et al., 2008; Lobach et al., 2012).

#### *6.6.1 Methods of evaluating CCDSSs in emergency care*

Only 3 RCTs were identified in the literature review of ED CCDSSs within this thesis (Roukema et al., 2008; Roy et al., 2009; Dexheimer et al., 2013). Lack of studies using an experimental design in EDs appear to support the arguments within the literature that RCTs are logistically difficult (Eccles et al., 2003), prone to contamination effects (Chuang et al., 2002) and when they are conducted are of low quality (Augestad et al., 2012). A very specific risk of bias when an RCT is conducted in an ED is that of contamination and subsequent performance bias (Chuang et al., 2002). In the studies by Roukema et al., (2008) and Dexheimer et al., (2013) children attending the ED were randomised before their triage assessment. This would mean that during the course of a shift it was highly likely that medical staff would be treating children with the same conditions (fever and asthma) with and without decision-support. In both these scenarios isolating the effects of the intervention would not be possible.

The process of designing and implementing this study has increased the researchers understanding regarding the appropriateness of an ITS design. The use of this design will further influence the methodological debates in the literature. In particular it adds to the current knowledge base regarding research methods that can be used to assess the impact of interventions already instituted in clinical practice. That is a valuable and unique contribution in its own right. Much of the discussion within this chapter and within the thesis as a whole has strongly advocated for the use of an ITS design study when evaluating the implementation of a CCDSS in an ED. However, this design as with any other is not without its limitations. The final sections within this chapter will discuss validity and reliability and specifically how aspects of validity can be enhanced with an ITS design. The limitations of the research are discussed and suggestions made regarding how they can be addressed in future studies.



## **6.7 Issues of validity and reliability**

Through the critical appraisal of studies in this thesis and careful consideration of the methodological challenges of CCDSS research in emergency care, an ITS design has been identified as eminently suitable method of enquiry. An ITS study does not have the same logistical constraints of an RCT. The randomising approach used within this study permitted a degree of confidence that the risk posed by confounding variables were evenly spread. In contrast, B&A studies that are most frequently used to assess the effects of decision-support in ED are prone to regression to the mean and do not enable the sustainability of any change to be identified (Bender, Connelly, Glaser, & Brown, 2012). This section will consider the validity and reliability of this study before a fuller discussion on its limitations.

An important feature of any study is the rigour within its design and the degree to which its results are valid and reliable (Peat & Barton, 2005; Polit & Beck, 2008). The selection of an ITS design in itself and the logistic regression analysis have contributed to increasing this study's internal validity. The fundamental question to be asked of any quantitative research when assessing the credibility of the results is, "are the results biased in any way?"

### ***6.7.1 Threats to internal validity***

The threats to internal validity considered within chapter 4 will now be revisited in light of the results and discussion, they are: selection bias, performance bias, historical changes, detection bias, attrition bias, reporting bias and regression to the mean. There was no bias in the selection of the triage records that were retrospectively analysed as they were selected using computer generated random selection algorithms. Although the patient characteristics were similar in the pre and post intervention groups the experience of the triage nurses were different. This was analysed in a logistic regression model to consider any relevant differences. As previously mentioned in section 6.3.1 a convenience sample of patients with potential neutropenic sepsis was used. It was the total population of patients with neutropenia but would not have been representative of those who presented with possible neutropenia but subsequently had a neutrophil count of

>1.0. The risks of performance and attrition bias were not relevant to this study. As the study was retrospective ED staff were not aware that their decisions were being judged. As patients were not being followed-up there was no risk of loss to follow-up.

#### *6.7.2 Historical changes*

Historical changes are a potential threat in ITS studies despite data being collected at multiple time points (Belcher, 2001). Triage nurse training remained the same over the whole study period and consisted of the standard 1 day MTS training programme (Advanced Life Support Group, n.d.). There were no specific audits undertaken of triage practice during the study that could have alerted staff to decision-making errors. However, there were regular audits on pain management as part of the national CEM audit programme (CEM, 2010a). These audits were presented to staff bi-annually during the whole study period. There were substantial improvements in pain assessment and management noted post eTriage. However, it is unlikely that audits during this period would have had any more impact than in the pre eTriage period.

With regard to neutropenic sepsis there were occasional training sessions in the pre and post intervention period together with posters in the ED displaying the pathway. These effects could not be isolated. A co-located children's ED opened in November 2011 which altered the triage process for children <16years of age. This meant that during the last study period children were more likely to be triaged by a children's nurse. This accounted for 19 patients in the last time period (Jan 2012). However children's nurses were in post during the whole study period and would have triaged children in the other time periods as well. There were no significant changes in numbers of staff in the ED during the course of the study although there were increases in patient attendances. Interruptions and multiple concurrent tasks are known to increase risk in ED and may effect the quality of decision making (Wears et al., 2003). These are more likely to occur with increasing attendances. The potential effect of increasing attendances on decision-making will be considered later in this chapter.

All the results of the primary and secondary outcome measures have been fully reported in this thesis. Negative results are equally important to communicate to ensure that reporting bias is reduced. The threat of regression to the mean has been avoided by using an ITS design. The underlying trends are clear before and after the introduction of eTriage and the impact 2 years post eTriage is evident. There was a specific date that the intervention was introduced (12<sup>th</sup> April 2010). EPOC (2013b) state that this is an important criteria for a ITS study as it avoids any diffusion effect from a poorly specified time that the intervention was introduced.

### *6.7.3 Detection bias*

Finally the risk of bias as a result of the data collection process will be examined. There are several issues that require discussion: blinding during data extraction and inter-rater reliability. The methods of data collection were identical during the course of the study i.e. data was extracted from the clinical record directly into an electronic database. Blinding during the data collection process is recommended to reduced bias in ITS studies (Ramsay, Matowe, Grilli, Grimshaw , & Thomas, 2003; EPOC, 2013a). However, in this study data extraction could not be blinded for practical and cost reasons. The issue of detection bias is a concern with regard to the triage cohort as the researcher made judgements about the accuracy of decisions. Pre intervention records were handwritten and post intervention records were typed, therefore it was obvious to the researcher which records were which. The researcher had designed and implemented eTriage and it could be argued had a vested interest in demonstrating its success. To guard against conscious or subconscious biases the researcher constantly referred to the reference documents when making judgements about the accuracy of decisions. When assessing the triage decisions common presentational flowcharts, e.g. chest pain and limb problem were displayed on a noticeboard. When less common presentational flowcharts had been used the researcher always referred to the MTS book (Mackway-Jones et al., 2006). When assessment were made regarding the appropriateness of analgesia the CEM guidelines were directly consulted (CEM, 2010c, 2010b) (See Appendices 8 & 9).

Together with these apparent safeguards inter-rater reliability testing was undertaken as a means of assessing how objective the measurements were (Ramsay et al., 2003). An independent experienced Emergency Nurse reviewed 80 records and the range of kappa scores suggested moderate to substantial agreement over what would be expected to occur by chance (Landis & Koch, 1977). The scores demonstrated are viewed as acceptable evidence of the reliability of measurement and is congruent with previous studies of MTS inter-rater reliability (van der Wulp et al., 2008; Grouse et al., 2009; Olofsson et al., 2009; Storm-Versloot et al., 2009; Parenti et al., 2014). Though, Ramsay et al (2003), in their quality criteria for ITS designs suggest a kappa of >0.8 or >90% would ensure objectivity in measurement. However they do not state why or how they arrived at these figures. When a kappa score is calculated it assumes that if a rater does not know the answer they guess (Viera & Garrett, 2005). In clinical practice and indeed in this situation it is unlikely that that either rater guessed their answer. EPOC (2013a) do not stipulate any kappa or inter-rater criteria. From the results of the inter-rater reliability testing in the research within this thesis one can conclude with a moderate degree of confidence that the process for data extraction and coding was robust. However, dependent on perspective the data collection processes within this study could be subject to some challenge.

#### *6.7.4 Missing data*

Another important area to discuss is that of missing data. Within the triage records there was missing data in the pre intervention cohort. Data can be regarded as missing if it was absent or illegible and can be a common problem when extracting information from handwritten records (Worster & Haines, 2004). Four studies within the literature review reported issues with missing data such as absent information or poor documentation (Roukema et al., 2008; Roy et al., 2009; Drescher et al., 2011; Lim et al., 2012). Missing data and the methods taken for handling it must be carefully assessed as they will have an impact on the results (Pallant, 2007; Higgins & Green, 2011). Within the descriptive analysis the majority of data was present as it was pre-recorded into the PAS database. Data

that was missing was excluded pairwise as suggested by Pallant (2007). In 41 cases the triage priority category (red, orange, yellow, green or blue) was missing in the pre eTriage group. It could have been replaced with an assumed outcome but a decision was made to record it as missing. The other significant area of missing data in the pre eTriage group was the triage nurses signature; in 89 cases it was missing or illegible. There were statically significant differences between the experience of the triage nurses pre and post intervention. It is not known whether an experienced or inexperienced triage nurse would omit their signature or have an illegible one. Any judgement regarding a pattern to this missing data is not possible and therefore the true estimate unknown. Once again in this case it was recorded as missing.

Finally, where decisions had to be made about the accuracy of decision-making a pragmatic approach was taken to handling the missing data. The approach used is one that is more commonly applied to medico-legal issues in health care

“if it’s not recorded it was not done”

McWay (2002) p 11

Assessments were being made regarding the following:

- Selection of the right chart
- Selection of the right discriminator
- Selection of the right priority
- Presence of a pain score
- Analgesia administered according to a recorded pain score

The assessment that was being made concerned the accuracy of a decision and this could only be judged if it was documented. Therefore, if it was not recorded it was coded as “no” in terms of its correctness. When it was recorded that patients had declined analgesia or had already taken it, they were coded positively (yes) as there was no “not applicable” coding category.

### *6.7.5 Generalisability*

The results of this study are not generalisable to a population outside the study ED as the investigation was specific to a bespoke system developed and used in one department. There is criticism within the literature that many findings from CCDSS research are not transferable beyond the research setting (Black et al., 2011; Lobach et al., 2012). Despite the volume of CCDSS research the wide variety of systems being investigated makes it difficult to identify the effectiveness of factors or features within systems (Lobach et al., 2012). Despite this issue this study contributes to the methods debate in the literature and identifies a study design suitable for the ED environment. Clinical-decision-making was significantly improved as triage nurses were more likely to select the correct discriminator with eTriage. This in turn resulted in a substantial improvement in the allocation of the correct clinical priority for patients when eTriage was used. This study also identifies that when “forcing functions” are used, i.e. the triage nurse can not continue until a pain score is entered that adherence to clinical standards is increased. There is a significant amount of learning that has taken place as a result of this study and disseminating that is vital. The final chapters in this thesis will discuss that further.

## **6.8 Limitations of the research**

The final section within this chapter will discuss the remaining limitations of this research not already addressed in the preceding validity and reliability section. These are: confounding variables, outcome measures and the time series data collection intervals.

### *6.8.1 Confounding variables*

The most common confounding variables identified within the literature review of CCDSSs in ED were: patient demographics (age, gender, and race), illness severity and clinician experience. Two studies on sepsis management considered the effects of overcrowding on timeliness measures (Lim et al., 2012; Bond et al., 2013). Overcrowding has only become a significant issue in US, UK, Canadian and

Australian EDs since the mid 2000s (Higginson, 2012), therefore earlier studies would not have considered it. When improvements in care processes and their timeliness are being measured it is important to consider what other factors may have an effect. Timeliness of antibiotics was measured in the neutropenic sepsis cohort. A delay to be assessed by a clinician, a delay in being allocated a cubicle (both features of overcrowding) and nursing staff shortages could all contribute to delays in drug administration. With regard to triage decision-making, a long queue of patients waiting for triage assessment could increase the stress the triage nurse felt to assess patients as quickly as possible, which may affect decision-making. Illness severity was considered in five studies as this could have had an independent effect on decision-making (Schriger et al., 2000; Busing et al., 2008; Kwok et al., 2009; Dexheimer et al., 2013; Jones, B. et al., 2013).

Although triage nurse experience was measured and analysed using logistic regression to assess its impact it was not feasible to address these other possible confounders. Long queues for triage could have affected decision-making, however the wait prior to triage is difficult to isolate as there is often a queue prior to registration as well. Prospective data collection would be required to assess this accurately.

The assessment of illness severity is of equal challenge. Kwok et al., (2009) used triage category as a marker of severity, however this was being assessed before and after the introduction of eTriage so could not be used. EWS could have been used but was not recorded in all patients and is not always directly linked to clinical priority (Mackway-Jones et al., 2006). The nursing and medical staffing establishment remained relatively unchanged during the course of the study but vacancies and staff sickness rates could have had an intermittent impact. Addressing all the possible confounding variables in this study would be very challenging and would have required some degree of prospective measurement which was not possible with cost and time constraints.

### *6.8.2 Outcome measures*

The primary and secondary outcome measures in this study considered the process of care e.g. was the patient's pain scored. The majority of CCDSS research evaluates process measures (Haynes & Wilczynski, 2010; Black et al., 2011; Sahota et al., 2011; Lobach et al., 2012). There is evidence within the literature that patient outcomes are much less frequently reported, and when they are, the evidence of effectiveness is weak (Haynes & Wilczynski, 2010; Black et al., 2011; Sahota et al., 2011; Lobach et al., 2012). The objectives of this research were to consider the effect of eTriage on the process of care in the ED. However the effect on patient outcome could also have been considered. Assessing the impact of pain relief by the collection of a post analgesia pain score would have been one way to do this and contribute to the evidence on patient outcomes. However, the focus of this study was on improvements in decision-making. Finally the limitations of the time series data collection points will be considered.

### *6.8.3 Time series data collection*

For a meaningful ITS analysis data should be collected for at least 3 time points before and after the introduction of the intervention (EPOC, 2013b). Within this study data was collected at four time points before and after the introduction of eTriage (see Table 4.2). There was a gap of 12 months after eTriage was introduced to enable the system to be embedded into practice and so that the longer-term decision-making trend could be analysed. However, this had unforeseen statistical consequences with regard to the logistic regression analysis. There was a gap of 15 months between the last pre eTriage data collection point (January 2010) and the first post intervention point (April 2012). This was interpreted in the statistical analysis as a sudden, huge jump in trend and led to the very wide CIs for the effect of the intervention noted in Tables 5.11 & 5.12. The underlying trends are demonstrated in Figures 5.13 & 5.14. The pre eTriage data was extrapolated forward to 24 months to give an estimate of the trend without an intervention effect for both correct discriminator and correct priority. Discriminator trend: expected with no intervention effect was 67.6% vs



fitted 86.7%. Priority trend: expected with no intervention effect was 60.1% vs fitted 86.3%. Although it is impossible to know what would definitively have happened without the intervention these estimates give a strong indication of a large intervention effect. In future studies the gap between the pre and post intervention data collection points should be narrowed to avoid this issue. The final section of this chapter summarises the discussion.

## **6.9 Summary**

This chapter has analysed the results of the research into eTriage and offers clear insights into its impact. This study makes an original contribution to the limited body of research in this area. The use of an ITS design has demonstrated a robust method to investigate CCDSS in emergency care. ITS design has increased the internal validity of the study in a complex uncontrolled clinical environment. Cause and effect cannot be confirmed with studies using an ITS design. However, this study demonstrates that the intervention, eTriage, was associated with statistically valid changes in the quality and safety of triage assessment. eTriage had the greatest independent effect on improving the accuracy of triage prioritisation and the assessment and management of patient's pain. This is a unique and significant finding that has not previously been identified. The results of the logistic regression identify that the experience of the triage nurse was not a factor in triage decision-making, thereby supporting part of the rationale for the development of eTriage, to support the inexperienced. When the impact of eTriage was investigated beyond the triage interaction there were no demonstrable benefits; the care of patients with potential neutropenic sepsis remained unchanged. There are several possible explanations for this requiring further exploration.

In conclusion, this study has demonstrated positive changes in decision-making at triage when eTriage was introduced. The results support the researcher's initial assumptions (in the most part) about the encouraging contribution of CCDSS in an ED. The next chapter in this thesis provides a brief reflective account of the researcher's experiences as a practitioner-researcher. The thesis then concludes

with the overall conclusion of the study, its unique contribution regarding the role of CCDSSs in emergency care and makes a series of recommendations.

## CHAPTER 7: REFLECTIONS ON THE ROLE OF THE PRACTITIONER RESEARCHER

### 7.1 Introduction

The following chapter critically reflects on my personal and professional journey to date as an experienced practitioner and new researcher. I have chosen to dedicate a chapter to critical reflection rather than weave the reflective element throughout the thesis. The two are not often seen sitting comfortably together as the objective nature of quantitative research does not recognise the need to contextualise (Bruce et al., 2008). However, as a practitioner researcher undertaking a Professional Doctorate the personal and practice influences on this research are a fundamental part of the doctoral journey (Lee, N. J., 2009). This chapter will also reflect on the context of the research and describe my learning during the last six years. There will be critical reflection on the personal challenges I faced and my professional and personal growth during my studies. Finally, in more general terms through this reflective process I will consider the value of practitioner research and its impact on practice.

### 7.2 My research journey

The eTriage journey began in 2005 with my involvement in a review of a Serious Adverse Event (SAE) described in Table 7.1

Table 7.1 Serious adverse event

*A young woman presented to the ED in 2005 with abdominal pain, a junior doctor assessed her, bloods were taken and it was identified that she was pregnant. She was discharged from the ED with follow-up on the Early Pregnancy Unit (EPU) the following day. When she presented to EPU the next day she was clinically shocked and required immediate emergency surgery. She had a ruptured ectopic pregnancy.*

*On review of the case it was identified that:*

- *Risk factors for ectopic pregnancy were not assessed in ED*

- *She was discharged home without specialty review (gynaecology) as per ED clinical guideline.*
- *On discharge from ED the gestation and site of the pregnancy was unknown: intrauterine or extrauterine*
- *The discharge information outlining signs and symptoms that required urgent assessment were not made clear to the patient*
- *Her care fell short of established practice*

I distinctly remember the conversation I had with the then Director of Nursing about the incident. She asked me how we could prevent this ever happening again. (This incident had similarities with other situations that had arisen where either junior doctors or locum doctors had not followed departmental clinical guidelines). I suggested that the only way to ensure the treating clinician had the relevant guideline to hand, when assessing a patient, was to develop a computerised triage system. This system would prompt the triage nurse regarding which guideline to print. An ED clinical record would be produced to document the patient's care containing all the relevant clinical information. I explained that to my knowledge a CCDSS that had a link to all departmental clinical guidelines did not exist. From this discussion the concept of eTriage was conceived and over the coming years I was instrumental in its development and implementation. Critical incident have been described as motivators for professional doctoral study (Wellington & Sikes, 2006).

The idea that a computerised system could address quality and safety in the ED was very appealing. In 2004 I had been appointed as a Nurse Consultant in the ED; I had responsibility for training, education, service development, audit and research. I was also responsible for developing a considerable number of clinical guidelines, ensuring staff were trained in their use and that they were accessible via the department's intranet site. I knew from regular departmental audit evidence that when care deviated from the established guidelines elements were

omitted e.g. follow-up would not be arranged. This caused me great personal and professional frustration as my efforts to change and then maintain practice often seemed to fail. Or at least it felt like it did, the SAE in Figure 7.1 being a perfect example. The concept of eTriage appealed to my need to find a fool proof way of ensuring clinical practice was always as it should be.

In the next section I consider these career-long frustrations when practice was below the required standard and my early assumption, based on my experiential knowledge that a CCDSS could “fix-it”.

### *7.2.1 The perfectionist in me*

I have reflected extensively on the origins of eTriage and the subsequent research study as my critical reflection skills developed. My clinical experience to date had been concerned with developing the practice of others. The usual methods I had employed – teaching, clinical guidelines, posters and audit – did not seem reliable as errors, sometimes significant, still occurred. Through the process of doctoral study I have reflected on those constant feelings of frustration. I have considered my drive to find a perfect solution in the form of a CCDSS. I have reflected on my feelings of responsibility when areas of practice I have developed were not followed correctly by staff and the unacceptable impact this could have on patient outcomes. I embarked on a process of critical reflection as described by Gardner (2006) to try to understand my assumptions, their origins and explore alternatives. The fact that there are omissions and errors in ED care is not an unfounded assumption (although I have considered that I may over-estimate the extent to which they happen). However, my presuppositions at the time did not have a robust evidence base. Through the process of doctoral research I am now well versed with the literature in this area. For example there is compelling international evidence that patients receive only approximately 50% of recommended care and that this is linked to deaths resulting from preventable medical errors (Institute of Medicine, 2000; McGlynn et al., 2003).

In the early part of my doctoral study I was introduced to the four individual learning styles described by Honey and Mumford (1982): theorists, activists, pragmatists and reflectors. Through reflection I have been able to see links between my learning styles and clinical experiences. I recognise that exploring the application of a CCDSS in ED care fits succinctly with the kind of person I am and the way I learn. When I consider my learning style I am open-minded, enthusiastic and thrive on trying out new ideas: the activist. However I also have elements of the pragmatist as I need to be able to see links between concepts and their immediate benefits. Despite being able to see some elements of an activist and pragmatist I see the strongest links with the theorist's analytical style, perfectionism and the need to fit things into a rational scheme. Having actively considered these learning styles it is clearer why I made an assumption very early on that a CCDSS was the right approach to use to address errors in practice. My assumption was that a CCDSS would ensure that what should happen to a patient would happen, at the right time, every time. However, this assumption was based purely on my knowledge of the practice environment and not on any robust evidence base. A technical solution to "fix" the problem of guideline adherence was very tempting. This met my need for perfection, seeing the immediate benefits of something and being able to try out new ideas. The realisation that my need to ensure practice was "perfect" had led me to a huge assumption about the role and value of CCDSSs. Challenging assumptions is well recognised in the development of scholarly practice in professional doctorates (Wellington & Sikes, 2006). The next section describes how the development of my critical thinking skills created a more balanced perspective on which to base my research.

### **7.3 Reflections on learning**

As an experienced practitioner I know how to manage the clinical situations I encounter and staff often ask me for advice. As a doctoral student however a significant number of my firmly held beliefs about practice were challenged through the process of developing and acquiring critical thinking skills. During the taught element of the doctorate extensive reading, completing assignments and debate and discussion with a wide range of colleagues facilitated this process.

Critical thinking involves being open to considering and then understanding alternative viewpoints (Paul & Elder, 2002).

As I embarked on my studies I had little detailed knowledge of CCDSSs, or awareness of their applications in healthcare or their capabilities in emergency care. However, I had an acute knowledge of the current challenges facing the speciality: increasing attendances, inexperienced or locum staff, departmental overcrowding, and challenging a performance target. I drew a very early conclusion that a CCDSS would be the panacea, in a similar way to many others (Black et al., 2011).

Through the process of critical thinking and critical appraisal I have developed skills that now enable me to have an awareness of my own epistemological positivist preferences. Following my extensive exploration of the literature on decision-support (which was necessary both for the literature review within this thesis and my own determination to identify an appropriate methodology) I have become acutely aware of how limited my knowledge was. Through this process I have developed reflective self-awareness described by Kondrat (1999) as the ability to be aware of one's biases and preferences.

In reviewing the emergency care evidence on CCDSS my appraisal skills and methodological knowledge increased. I now have a comprehensive understanding of what CCDSSs in EDs can and cannot do and the status of the current evidence base. I recognise that my need to find a solution for practice has, to some extent, prevented me from considering other options that might equally have helped for example exploring how effective decision-making at triage is developed. However, I now have a more balanced view of what CCDSSs can do, what the evidence states about their effectiveness and the challenges of this type of research in an ED.

During the taught element of my doctoral studies, immersion in the research process, critical reflection and critical thinking has facilitated consideration of a wider range of alternatives to support the development of practice than I wouldn't have previously considered. I recognise my earlier need to "fix-it" has

limited my creativity as I have had a tendency to draw conclusions too early. The process of doctoral study has raised an awareness of this issue within my consciousness and has been the first step in recognising its restrictive effects. This realisation has led me to reflect on what has drawn me to emergency nursing as my chosen speciality and how this area of practice has shaped my views and contributed to the research I have undertaken.

As part of my Professional Doctorate studies I underwent Enneagram® personality testing. This was extremely useful in illuminating my personality traits, how react to situations and how I work as part of a larger team. My Enneagram® type is One (Perfectionist). As described earlier I had already recognised this trait. Completing the Enneagram® created the time and space for me to consider my behaviours at a deeper level. I have reflected on the characteristics of a Type One: noticing and correcting errors, identifying and adhering to standards of perfection in thought, feeling and behaviour, acting according to what is right or wrong and judging and criticising oneself and others (Riso & Hudson, 1999)

Having reflected on these traits I have a deeper understanding of what drives and motivates me and what has ultimately sustained my impetus over the last six years. I have found my doctoral journey immensely challenging and frustrating. My motivation waned (and sometimes completely disappeared) many times and coincided with areas in my studies which posed the greatest intellectual challenge, namely developing competence and confidence in statistical analysis. As a clinical expert, well established in my career developing a detailed knowledge of statistics was a completely new area to me. It has been a long and tortuous journey with many ups and down. As I reflect on this part of the journey and how I eventually mastered statistical concepts and procedures there has been even more personal learning for me.

Developing statistical skills has undoubtedly been the most difficult, perplexing and exasperating process I have ever undertaken. However, by trial and error, by identifying and accessing guidance from experienced statisticians and perseverance in the face of significant cognitive challenge, I now have a solid



understanding of statistics and a whole set of new skills in conquering this significant intellectual challenge. In mastering all the challenges I faced whilst undertaking this study I have increased my resilience, particularly when under pressure. I have more confidence in my abilities and this enables me to be more resourceful. I am ambitious, which has enabled me to maintain clarity of purpose within my research endeavours and has maintained my overall direction and the achievement of my research goals. I am more confident in my abilities to cope under pressure but equally I am able to recognise when I reach my limits and need “time out”. And finally, through the process of doctoral study I have been able to harmonise the recognised tensions of being steeped in practice (Malfroy, 2004), yet “stand back” far enough to ensure that evidenced-based solutions are not abstract or conceptual. I have ensured my research and its recommendations are highly relevant and applicable, with the power to truly make a difference. This personal ambition is consistent with professional doctorate literature which identifies a primary driver of making recommendations to underpin practice (Malfroy, 2004; Wellington & Sikes, 2006; Smith, N. J., 2013b)

When faced with challenges as a Nurse Consultant I have decades of experience to draw upon, clinical resources at my fingertips and colleagues to ask for advice. But I also work in a clinical environment where there is little time to reflect or consider a range of options. Smith and Feied (1999) describe the ED as a

*“unique operation optimised to exist on the edge of chaos”*

Smith and Feied (1999)p 5.

The nature of ED clinical work demands rapid decision-making and action, which has been further compounded by the performance target introduced in 2001 (DH 2010). During my doctoral studies I have reflected on all these interrelated aspects of my career and the type of person I am and I have reached a new understanding. I recognise more clearly the origins of my drive, commitment to improving care and my “staying power”. I understand why I have been drawn to CCDSS research and how I must ensure I remain objective, curious and critical throughout my future research career. Through a long process of reflection I have

a greater appreciation of my drivers and that I now lean towards a more objective, positivist approach. The next section of this chapter considers the changing context of the eTriage research before concluding with reflections on the value of practitioner research.

#### **7.4 Reflections on the context of the research**

My doctoral studies began in 2008 as eTriage was being developed. At that time there was a single performance target for emergency care areas: all patients had to be seen, admitted or discharged within four hours (DH, 2001). In April 2010 eTriage was launched and by April 2011 the new A&E Clinical Quality Indicators were in place (DH, 2010). Within the new suite of indicators there was no emphasis on triage, in fact it is not mentioned but replaced with the term “initial assessment” for patient arriving by ambulance. The indicators state that initial assessment for patients with minor injuries should not be in place if it creates any extra steps (DH, 2010). These indicators stimulated significant debate in clinical practice and in the literature regarding the future of triage and that it was now deemed superfluous (Windle & Mackway-Jones, 2003; Hughes, 2006). This specific issue was a threat to my research. If triage was no longer required as political drivers had changed, what would become of my research? I was faced with the prospect of studying a process that may very well become redundant in emergency care in the near future.

It took me some time to realise that even if eTriage was removed and another system was put in place I could still continue with my research. I sought advice from my supervisors and other experienced clinical researchers to enable me to gain a more balanced perspective. Data was available to enable me to evaluate the system and even if the system was removed the results of the study were still of great value. The research was considering the impact of e CCDSS in an ED, it was not a study of triage practice. I also recognised that in an ever-changing health care climate when a research project is being carried out over a number of years issues like this were common and often inevitable (Clancy, 2007). In light of this I have learnt a significant amount about: managing threats to research,

adapting research plans and drawing on sources of advice. I was able to do this through support and advice from a new network of doctoral and research colleagues and through critical reflection. The final section in the chapter will consider the impact of practitioner research and the value and challenges of having clinicians actively engaged in research in practice.

## **7.5 The impact of practitioner research**

My doctoral journey has been a very personal one. For me, completing a Professional Doctorate has been the final piece of my career jigsaw as a Nurse Consultant. The creation of Nurse Consultant posts in the UK in the 1999 held immediate appeal to me (NHS Executive, 1999). The four domains of the role: 1) expert clinical practice, 2) education, training and development 3) practice and service development, research and evaluation 4) professional leadership and consultancy mirrored my own attributes and skills (with the exception of research) and my deep rooted beliefs regarding value of expert practitioners working in and through clinical teams (Ryan, Hassell, Thwaites, Manley , & Home, 2006). My professional goals and aspirations have always been to develop practice creatively by finding workable solution to clinical problems.

I now recognise that the clinical environment I work in has stifled my creativity to some degree. The fast-paced nature of work in the ED leaves little time for reflection or the refinement of reflective skills. I have also considered the development of research knowledge and skills in a non-academic environment such as mine. My doctoral journey has been a lonely one at times. This is a recognised concept in doctoral students and one which contributes to them not completing their studies (Kearns, Gardiner, Marshall , & Banytis, 2009; Janta, Lugosi , & Brown, 2014). In my Professional Doctorate cohort of ten students I was the only one undertaking a quantitative study. This created a certain sense of isolation but conversely I learned about other research methodologies which significantly enhanced my knowledge base as I contrasted various approaches. Working in a non-academic environment restricted my immediate access to clinical researchers with whom I could discuss the research challenges I faced. I

sought other opportunities to network by attending conferences, developing email contacts with researches in the same field and discussing my study (at every opportunity) when I met fellow researchers.

However, despite these limitations, which at times felt very significant I have achieved my goal. For me, this thesis embodies professional doctoral research. A problem was identified (risks to clinical quality and safety), a possible solution was developed and implemented (eTriage) and a research study was undertaken to evaluate the impact of the proposed solution on practice. The research within this thesis has been a vehicle through which a service development has been evaluated but even more importantly it has been about improving clinical practice for patients, families and colleagues alike. As Nurse Consultant I now feel more credible and have additional skills to be more effective in my clinical role. Nurse Consultants with highly developed skill have been shown to have a significant positive impact on colleagues (Manley, Webster, Hale, Hayes , & Minardi, 2008; Jarman, 2009). So despite the challenges I faced and the limitations I perceived that resulted from isolation, they were not insurmountable.

## **7.6 Summary**

My Professional Doctorate journey has been a great personal and intellectual challenge combined with deep-rooted drivers of personal development and scholarly endeavour. I am a different person and a different nurse by engaging in this process. There are further challenges ahead as I aim to continue developing and researching CCDSS in ED. I also plan to share my knowledge of this journey and the skills I have learnt with a small but growing number of doctoral nurse researchers within my organisation. There will always be the challenge of creating “space” in practice for clinical research. The completion of this thesis has undoubtedly confirmed that this is a critical part of any clinical activity and one that I am determined to develop as it will cement the foundations for my future clinical/academic career.

## **CHAPTER 8: CONCLUSION AND RECOMMENDATIONS**

### **8.1 Introduction**

The final chapter of this thesis reviews the aims and objectives of the research and revisits the research question in light of this study's findings. There is a brief summary of the thesis which highlights the key stages in the research and the research findings. The unique contribution of this research is emphasised and how it can further inform EDs considering the use of decision-support. The final section of this chapter makes a series of recommendations for future studies and for clinical practice.

### **8.2 Aim and objectives of the research**

The aim of this research was to test the researcher's assumption that computerised decision support at the point of triage is an effective means of improving the quality and safety of clinical care in ED. The objectives of the research were to:

- 1) To compare the decision making of triage nurses before and after the introduction of eTriage
- 2) To compare the quality of pain assessment and management before and after the introduction of eTriage
- 3) To investigate the ability of eTriage to improve the care of patients with potential neutropenia sepsis, a condition associated with significant morbidity and mortality

The aim and objectives of this research were achieved. The researcher's postulation about eTriage was tested through a rigorous approach using a quasi-experimental method based on ITS design.

### **8.3 Research question**

The research question was:

*Does the introduction of a computerised clinical decision-support system eTriage improve the quality of triage decisions and safety within the ED?*

The overall conclusion to this research identifies that eTriage has demonstrated a statistically significant increase in accurate prioritisation decisions at triage together with statistically significant improvements in the assessment and management of pain. These improvements have been above the underlying trend. Accurate triage prioritisation decisions are inherently linked with overall departmental safety as they ensure patients with urgent health needs are treated immediately (Cioffi, 1999; Considine, Ung, & Thomas, 2000; Smith, A. & Cone, 2010). As triage and ED safety are so closely related there is a significant degree of confidence in concluding that eTriage does improve safety. However, when a discrete aspect of safety was considered using a subset of patients, those with neutropenic sepsis, no clear improvements could be demonstrated. This is likely to be due to the sample size and/or system design.

Quality improvements were measured by identifying the number of patients before and after the introduction of eTriage that had appropriate pain assessment and pain management. Pain is a common feature in many clinical presentations in ED and it is often poorly managed (Fry et al., 2011; Body & Foex, 2012). However, when it is managed well there is a direct correlation with increased patient satisfaction (Bhakta & Marco, 2014). eTriage demonstrated a statistically significant increase in pain scoring at triage and the subsequent administration of appropriate analgesia. From these results there is a significant degree of confidence that eTriage does improve the quality of pain management.

### **8.4 Summary of the thesis**

Within the background and context chapter a number of drivers were identified that culminated in the development of eTriage. The most topical and significant of these drivers being: increasing ED attendances, the reduction in an experienced

workforce and the global economic climate (CEM, 2013b; Health Select Committee, 2013a; Kings Fund, 2013; NHS Institute for Innovation and Improvement, n.d.). These factors created the perfect opportunity to explore the benefits of CCDSSs. The researcher led the development of a CCDSS, eTriage, to support decision-making and provide a direct link to departmental clinical guidelines for clinicians in ED.

A comprehensive review of the literature in chapter 3 identified 23 studies that had investigated the use of CCDSSs in EDs. This provided, for the first time, a clear understanding of the types of systems used and the areas of clinical practice they were supporting. Through a robust critical appraisal process it was identified that the majority of these studies were of intermediate or poor quality due to threats to internal validity. The number of high quality studies was small. The challenge of identifying and implementing an appropriate research method in a complex clinical environment was also identified. This led to the formulation of a quasi-experimental design using ITS methodology.

To investigate the impact of eTriage on quality and safety a retrospective random sample of records was analysed. Data was extracted over one year, at four time points prior to the introduction of eTriage (n=400). One year post implementation data was extracted from a further four time points (n=400). In total 800 records were reviewed and judgements made about the accuracy of triage decisions and the quality of pain assessment and management. Data was extracted and coded for analysis using SPSS and analysed using descriptive and inferential statistics and logistical regression analysis.

Data analysis was based on an ITS study of antibiotic prescribing in an ED by Busing et al (2008). The results revealed a statistically significant improvement in the accuracy of triage decisions over and above the expected underlying trend. The logistic regression identified that mode of arrival had an influence on correct prioritisation but triage nurse experience did not. By far the most significant impact was eTriage, with an OR of 29.76 for the selection of the correct discriminator. There were also statistically significant improvements in pain

scoring and pain management when eTriage was used. However, when the process of care for patients with neutropenic sepsis was compared before and after the introduction of eTriage, no differences were observed.

The discussion of the findings of this study concluded that eTriage does provide a positive contribution to quality and safety over and above those initiatives already in place. The design of this study has increased its internal validity and provides a robust process through which the benefits of interventions can be investigated. The process of developing eTriage and subsequently investigating it been a significant undertaking and provides an important contribution to the small ED CDSS evidence base. The next section describes the unique contribution of this research and how it can further inform clinicians, managers and developers who are considering the use of decision-support in ED.

### **8.5 The unique contribution of this research**

This study adds to the limited body of published research on the impact of CCDSSs in emergency care. The significant contributions of this research are:

- The extensive literature view identifies, for the first time, the CCDSS research specific to ED clinical practice. It describes the range of systems in use and the methods used to investigate them in this complex clinical environment.
- Through a robust process of critical appraisal within the literature review the validity of the results of the published research in EDs has been identified and the paucity of high quality studies exposed.
- Through a critical review of the literature the specific methodological issues that require careful consideration when planning CCDSS research in an ED have been identified.
- The methods used within this research were carefully planned in light of the existing studies to ensure a robust design. This confers a significant degree of confidence in the results.



- The results of this research support the researcher's initial assumption that eTriage would improve the quality and safety of triage decision-making. The use of an ITS design demonstrates that the improvements to patient management are above what would be expected if eTriage had not be introduced.
- The results of this research provide a unique and significant contribution to the existing CCDSS knowledge base. There are several statistically significant findings
  - eTriage improved the accuracy of triage prioritisation decisions
  - eTriage improved the consistency of pain scoring
  - eTriage improved the administration of appropriate pain relief
- Finally, the use of eTriage did not significantly improve the process of care for patients with possible neutropenic sepsis and further research in this area is warranted.

This thesis provides a comprehensive overview of the research that has investigated the use of computer decision-support in ED. For those clinicians and managers exploring the benefits of CCDSS in emergency care the findings within this research are of great value. It is well documented in health care systems across the world that the wholesale adoption of technology in health care is not always based on robust evidence (Haynes & Wilczynski, 2010; Black et al., 2011). This thesis seeks to redress this balance for clinicians working in emergency care. It offers a measured and critical review of the studies that can help inform others embarking on CCDSS ventures. Within the complex environment of emergency care and the risk associated with time critical interventions, a measured approach is required to ensure one area of risk is not exchanged for another (Handel et al., 2011). The NHS has benefitted considerably from the technology already introduced e.g. NHS mail and PACS (DH, n.d.-e, n.d.-a). However caution is advised regarding the adoption of any system that has not been rigorously evaluated.

The research methods knowledge gained through reviewing the evidence and conducting this study is of significance. ITS design is an eminently suitable method for evaluation research in an emergency department. They are relatively simple to undertake, are cost effective and perfectly suitable for retrospective data collection. Statistical analysis can consider confounding variables and isolate the effect of the intervention. Exposing the underlying trend in the data increases the internal validity of the study in a way that the more common B&A study cannot. The ability to identify if any change in process or outcomes is sustained can be achieved with this method and a lasting trend identified. ITS design cannot conclusively say that an intervention caused a specific change in process, outcome or behaviour but it can identify statistical significance. All of these insights are of value to clinicians, researchers, managers and developers wanting to explore the benefits of their own systems

Finally, the negative results from this study should further highlight that the expectations of CCDSSs are not always met. The management of high-risk clinical conditions that present infrequently to EDs remain a continued challenge for clinicians. Protocolised care for these patient groups has been shown to reduce morbidity and mortality (Bond et al., 2013). How CCDSSs are developed is critical to ensure that their potential is optimised (Bates et al., 2003). Clinicians and managers must consider CCDSSs as another tool to compliment and supplement those already in use to enhance clinical quality, safety and guideline adherence.

This thesis has not been able to comprehensively cover everything that researchers, clinicians, managers and developers must consider. Additional understanding should be gained by identifying the views of users and patients when decision-support is being used. In the current economic climate a thorough economic analysis should also take place before embarking on developing or purchasing any system. However, the presence of risk, the critical nature of clinical work in emergency care and the role of CCDSS warrants our fullest and earliest attention. The final section of this thesis makes a series of recommendations for future research and clinical practice.

## 8.6 Future recommendations

The following recommendations relate to a future research agenda that this study has identified and further CCDSS developments

1. The publication of a series of research papers covering:
  - a. The use of computerised clinical decision-support systems in emergency care: what do they do and how effective they are.
  - b. A quantitative study exploring the impact of a computerised clinical decision-support system on quality and safety in an Emergency Department.
  - c. Interrupted time series design as a method for evaluating the impact of interventions in emergency care.
2. When preparing manuscripts for publication recognised guidance should be followed on how to report the results of evaluation studies in health informatics (Talmon et al., 2009). This will help to ensure that those investigating the evidence base have a clear understanding of the clinical context and decision-support system in use as well as the methods, results and overall conclusion.
3. Further research that explores the relationship between mode of arrival and accuracy of decisions at triage is warranted. This was an unexpected and unexplained finding and requires further investigation.
4. CCDSS research that investigates patient outcomes as well as care processes in ED is under-investigated. Further research should focus on patient outcomes as well as care processes.
5. Research that considers high-risk patient groups is still needed despite the negative outcome in this study. The researcher is in a unique position to investigate this further with the current system in use. In June 2013 eTriage was replaced with an ED EPR that will enable computerised decision-support throughout the whole ED journey. The ED EPR is a bespoke system with flexible functionality so that elements of decision support can be specifically tailored.

6. Finally, further developments with the current ED EPR be instituted following a detailed review of the evidence regarding factors known to increase effectiveness of a CCDSS (Bates et al., 2003; Kawamoto, Houlihan, Balas , & Lobach, 2005; Lobach et al., 2012; Roshanov, P. et al., 2013).

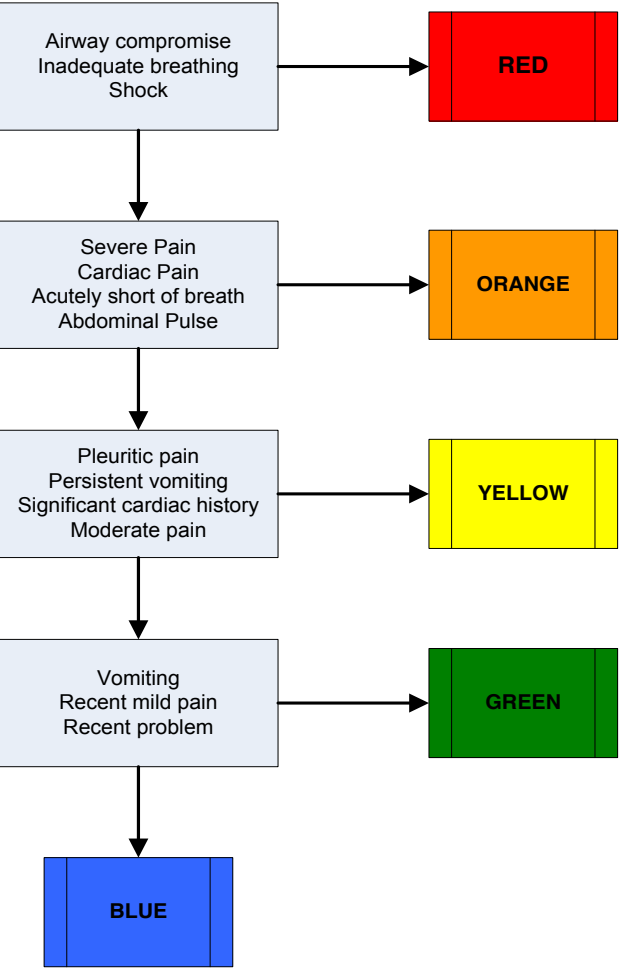
#### *8.6.1 Implications for practice.*

There are implications for clinicians, managers and developers both at a local, national and international level as a result of this research. There is significant support from policy makers to implement technological solutions across all aspects of of healthcare. However there is little rigorous evidence to support wholesale adoption in the NHS or other healthcare systems, particularly with decision-support (Black et al, 2011). Many of the studies reviewed, in common with this study, examine a bespoke system used in a single ED. The effectiveness of these systems, if used elsewhere is unclear .

Despite urging a cautious approach the research in this thesis has demonstrated the significant benefits of a triage CCDSS for ED patients. The importance of rigorous evaluation of any system cannot be over-emphasised. This will ensure clinicians and managers are aware of how and when CCDSSs can improve upon existing quality and safety strategies and when they cannot. Those embarking upon CCDSS developments must ensure there systems are based on functionality that has been shown to improve effectiveness (Bates et al., 2003; Kawamoto, Houlihan, Balas , & Lobach, 2005; Lobach et al., 2012; Roshanov, P. et al., 2013). ITS design could then be used as a relatively inexpensive and efficient method of evaluation.

In conclusion this research has demonstrated that the development and introduction of eTriage has been a very worthwhile and successful undertaking. The research was robustly deigned, conferring a considerable degree of confidence in the results, ED safety has been significantly improved and the quality of the patient experience has been greatly enhanced.

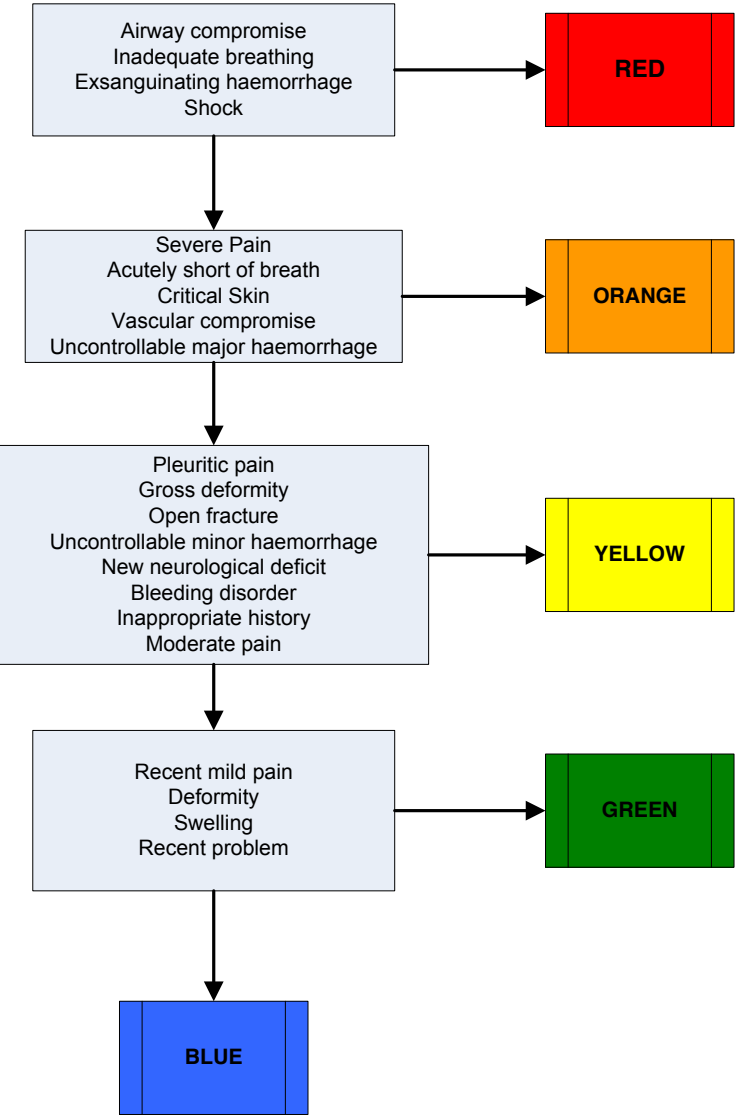
**Appendix 1 – Chest Pain presentational flow chart – adapted from the MTS (Mackway-Jones et al., 2006)**



This is a presentation defined flow diagram. Chest pain is a common presentation to Emergency Departments forming some 2-5% of all patient contacts. Causes of chest pain may vary from acute myocardial infarction to muscular irritation, and appropriate categorisation is paramount. A number of general discriminators are used including Life Threat and Pain. Specific discriminators include the nature and severity of pain (cardiac or pleuritic) and abnormalities of pulse.

Specific Discriminators	Explanation
Cardiac Pain	Classically a severe dull 'gripping' or 'heavy' pain in the centre of the chest, radiating to the left arm or to the neck. May be associated with sweating and nausea.
Acutely short of breath	Shortness of breath that comes on suddenly, or a sudden exacerbation of chronic shortness of breath.
Abnormal pulse	A bradycardia (<60 min in adults), a tachycardia (>100 min in adults) or an irregular rhythm. Age appropriate definitions of bradycardia and tachycardia should be used in children.
Pleuritic pain	A sharp localised pain in the chest worse on breathing, coughing or sneezing.
Persistent vomiting	Vomiting that is continuous or that occurs without any respite between episodes
Significant cardiac history	A known recurrent dysrhythmia which has life threatening effects is significant as is a known cardiac condition that may deteriorate rapidly.

Appendix 2 – Limb problem presentational flow chart - adapted from the MTS (Mackway-Jones et al., 2006)



This is a presentation defined flow diagram. Injuries to the limbs are the commonest presentation to Emergency Departments and, while rarely life threatening, may cause considerable morbidity. A number of general discriminators are used including Life Threat, Haemorrhage and Pain. Specific discriminators are included to ensure that limb threatening injuries are seen and treated urgently. Discriminators are also included to remind the triage practitioner to consider the signs and symptoms of thromboembolic disease and its complications.

Specific Discriminators	Explanation
Acutely short of breath	Shortness of breath that comes on suddenly, or a sudden exacerbation of chronic shortness of breath.
Critical skin	A fracture or dislocation may leave fragments or ends of bone pressing so hard against the skin that the viability of the skin is threatened. The skin will be white and under tension
Vascular Compromise	There will be a combination of pallor, coldness, altered sensation and pain with or without absent pulses distal to the injury.
Pleuritic pain	A sharp, localised pain in the chest made worse on breathing, coughing or sneezing.
Gross deformity	This will always be subjective. Gross and abnormal angulation or rotation is implied.
Open fracture	All wounds in the vicinity of a fracture should be regarded with suspicion. If there is any possibility of communication between the wound and the fracture the fracture should be assumed to be open.
New neurological deficit	Any loss of neurological function including altered or lost sensation, weakness of the limbs (either transiently or permanently) alterations in bladder or bowel function.
Bleeding disorder	Congenital or acquired bleeding disorder
Inappropriate history	When the history (story) given does not explain the physical findings it is termed inappropriate. This is important as it is a marker of non-accidental injury in vulnerable children and adults and may be the sentinel for abuse
Deformity	This will always be subjective. Abnormal angulation or rotation is implied.
Swelling	An abnormal increase in size.

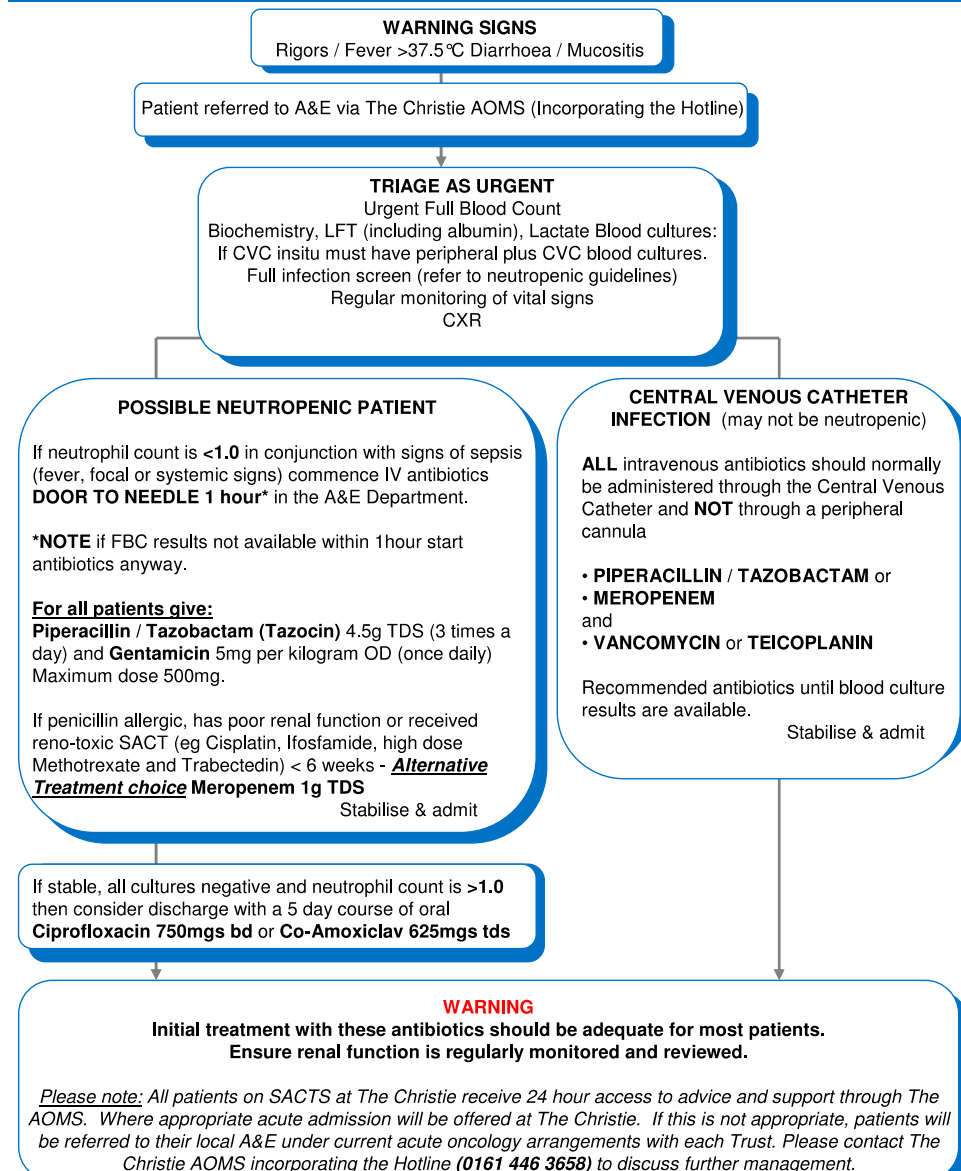
### Appendix 3 - Documentation used for the triage assessment pre-eTriage

Breach Time	Consultant	Please Get:-	Cubicle No.	Priority										
		Case Notes												
Waiting time		ED Cards												
Presenting Complaint				Triage Time										
History														
<table border="1"> <tr> <td>EWS Required</td> <td>Yes</td> <td>No</td> <td colspan="2">Discriminator</td> </tr> <tr> <td>Alcohol Related</td> <td>64</td> <td></td> <td colspan="2"></td> </tr> </table>					EWS Required	Yes	No	Discriminator		Alcohol Related	64			
EWS Required	Yes	No	Discriminator											
Alcohol Related	64													
Pain 0 1 2 3 / 4 5 6 / 7 8 9 10 R1 O2 Y3 G4 B5 See & Treat														
Stream: Resus. Minors Majors Psychiatry Primary Care														
Analgesia:- Required COMPLETE PAGE 2 Home Declined														
Triage Referral To:-			Signature:											
ADMISSION			DISCHARGE											
TIME	SIGNATURE		TIME	SIGNATURE										
Speciality			ED Review	GP Nurse										
Ward/Hospital			# Clinic	Physio										
Time Bed Available			BID	Eye Clinic										
			EPU	OP/ Other										
			ENT	GP Follow Up										
				NFU										
				Ref Treatment										
				DNW										

Circle as required

## Appendix 4 – Neutropenic Sepsis pathway (Haji-Michael, 2010)

### Management of patients with signs of sepsis following Chemotherapy treatment or with a possibly infected Central Venous Catheter (CVC)





### Appendix 5 - Medline search strategy

Search ID	Search Terms	Search Options	Results
S1	computer assisted decision making	Search modes – Boolean/Phrase	2415
S2	computer assisted instruction	Search modes – Boolean/Phrase	9162
S3	decision support systems	Search modes – Boolean/Phrase	6561
S4	reminder systems	Search modes – Boolean/Phrase	2292
S5	clinical decision support system	Search modes – Boolean/Phrase	533
S6	computerised clinical decision support system	Search modes – Boolean/Phrase	7
S7	computerized clinical decision support system	Search modes – Boolean/Phrase	47
S8	computer decision support	Search modes – Boolean/Phrase	498
S9	decision aid	Search modes – Boolean/Phrase	2413
S10	computerised decision aid	Search modes – Boolean/Phrase	6
S11	computerized decision aid	Search modes – Boolean/Phrase	43
S12	computerised decision support	Search modes – Boolean/Phrase	127
S13	computerized decision support	Search modes – Boolean/Phrase	600
S14	cdss	Search modes – Boolean/Phrase	156
S15	(MM “Decision Support Systems, Clinical “)	Search modes – Boolean/Phrase	3261
S16	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15	Search modes – Boolean/Phrase	22587
S17	accident and emergency	Search modes – Boolean/Phrase	8629
S18	emergency department	Search modes – Boolean/Phrase	67403
S19	emergency care	Search modes – Boolean/Phrase	19709
S20	A&E	Search modes – Boolean/Phrase	80586
S21	emergency service	Search modes – Boolean/Phrase	47017
S22	urgent care	Search modes – Boolean/Phrase	1924
S23	unscheduled care	Search modes – Boolean/Phrase	199
S24	(MM “Emergency Service, Hospital”)	Search modes – Boolean/Phrase	25909
S25	(MM “Ambulatory Care”)	Search modes – Boolean/Phrase	15067
S26	S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25	Search modes – Boolean/Phrase	200854
S27	S16 AND S26	Search modes – Boolean/Phrase	651

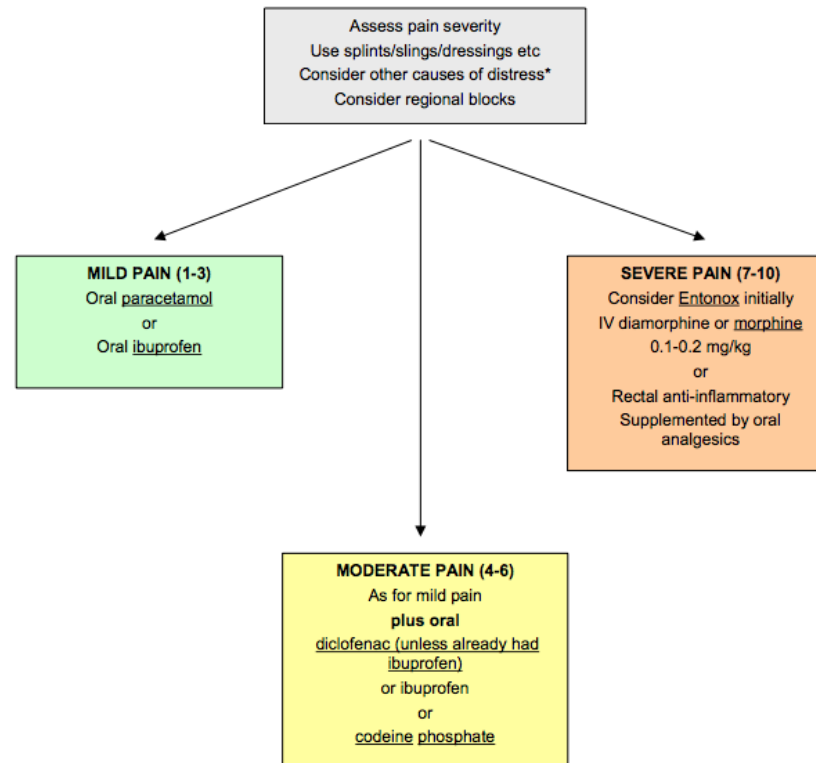
**Appendix 6 - EMBASE search strategy**

Line	Database	Search Term	Results
1	EMBASE	(computer AND assisted AND decision AND making).ti,ab	309
2	EMBASE	(computer AND assisted AND instruction).ti,ab	688
3	EMBASE	(decision AND support AND systems).ti,ab	5032
4	EMBASE	(reminder AND systems) .ti,ab	606
5	EMBASE	(clinical AND decision AND support AND system).ti,ab	2501
6	EMBASE	(computerised AND clinical AND decision AND support AND systems).ti,ab	86
7	EMBASE	(computerized AND clinical AND decision AND support AND systems).ti,ab	421
8	EMBASE	(computer AND decision AND support).ti,ab	2050
9	EMBASE	(decision AND aid).ti,ab	5579
10	EMBASE	(computerised AND decision AND aid).ti,ab	33
11	EMBASE	(computerized AND decision AND aid).ti,ab	144
12	EMBASE	(computerised AND decision AND support).ti,ab	289
13	EMBASE	(computerized AND decision AND support).ti,ab	1288
14	EMBASE	cdss.ti,ab	985
15	EMBASE	Exp DECISION SUPPORT SYSTEM/	13401
16	EMBASE	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15	24360
17	EMBASE	(accident AND emergency).ti,ab	7876
18	EMBASE	(emergency AND department).ti,ab	62514
19	EMBASE	(emergency AND care).ti,ab	57332
20	EMBASE	AandE.ti,ab	40
21	EMBASE	(emergency AND service).ti,ab	14049
22	EMBASE	(urgent AND care).ti,ab	9752
23	EMBASE	(unscheduled AND care).ti,ab	1577
24	EMBASE	*EMERGENCY CARE/	5664
25	EMBASE	*EMERGENCY HEALTH SERVICE	39031
26	EMBASE	17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25	143142
27	EMBASE	16 AND 26	906
28	EMBASE	27 [Limit to: English Language]	839

### Appendix 7 - CINAHL search strategy

Search ID	Search Terms	Search Options	Results
S1	computer assisted decision making	Search modes – Boolean/Phrase	763
S2	computer assisted instruction	Search modes – Boolean/Phrase	4380
S3	decision support systems	Search modes – Boolean/Phrase	1937
S4	reminder systems	Search modes – Boolean/Phrase	1277
S5	clinical decision support system	Search modes – Boolean/Phrase	163
S6	computerised clinical decision support system	Search modes – Boolean/Phrase	0
S7	computerised clinical decision support system	Search modes – SmartText Searching	650
S8	computerized clinical decision support system	Search modes – Boolean/Phrase	17
S9	computer decision support	Search modes – Boolean/Phrase	112
S10	decision aid	Search modes – Boolean/Phrase	635
S11	computerised decision aid	Search modes – Boolean/Phrase	2
S12	computerized decision aid	Search modes – Boolean/Phrase	12
S13	computerised decision support	Search modes – Boolean/Phrase	46
S14	computerized decision support	Search modes – Boolean/Phrase	189
S15	cdss	Search modes – Boolean/Phrase	107
S16	(MM “Decision Support Systems, Clinical “)	Search modes – Boolean/Phrase	895
S17	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16	Search modes – Boolean/Phrase	9401
S18	accident and emergency	Search modes – Boolean/Phrase	2118
S19	emergency department	Search modes – Boolean/Phrase	17577
S20	emergency are	Search modes – Boolean/Phrase	21298
S21	A&E	Search modes – Boolean/Phrase	2088
S22	emergency service	Search modes – Boolean/Phrase	25998
S23	urgent care	Search modes – Boolean/Phrase	792
S24	unscheduled care	Search modes – Boolean/Phrase	92
S25	(MM “Emergency Service, Hospital”)	Search modes – Boolean/Phrase	13435
S26	S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25	Search modes – Boolean/Phrase	49223
S27	S17 AND S26	Search modes – Boolean/Phrase	283

## Appendix 8 Acute pain management guidelines for adults (CEM 2010b)



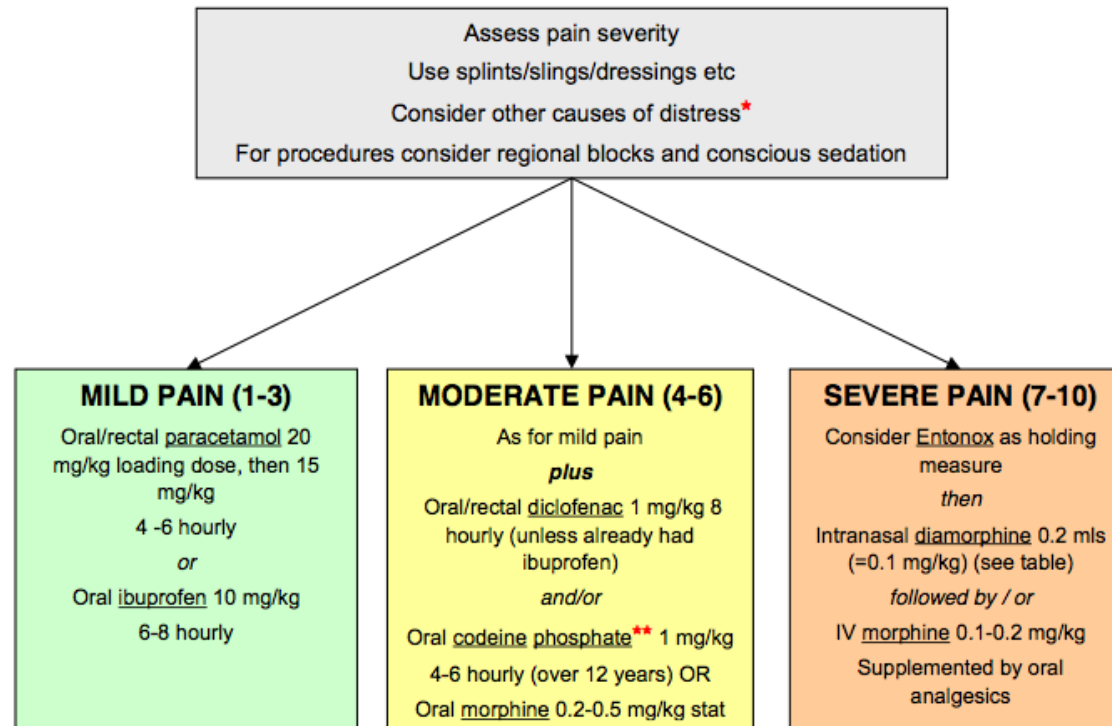
\*Other causes of distress include: fear of the unfamiliar environment, needle phobia, fear of injury severity etc.

### CONTRA-INDICATIONS:

**Ibuprofen/diclofenac:** avoid if previous reactions to NSAID's or in moderate or severe asthmatics

**Intravenous morphine:** use with caution if risk of depression of airway, breathing or circulation.

## Appendix 9 Acute pain management guidelines for children (CEM 2010c)



\*Other causes of distress include: fear of the unfamiliar environment, parental distress, fear of strangers, needle phobia, fear of injury severity etc.

\*\* The MHRA has restricted use of codeine to those over 12 years of age <sup>(9)</sup>

**Most children can and are able to use entonox, remember this may be a valuable source of analgesia whilst waiting for oral analgesia to work.**

**Appendix 10 - Pilot data extraction tool**

AMB      WALK-IN      MAJORSTREAM      MINOR STREAM      SEE &amp; TREAT

<b>Pt ID</b>					
<b>Triage</b>					
Presenting Complaint documented	Yes	No			
Correct Discriminator	Yes	No	Blank		
Correct decision/priority	Yes	No			
<b>Pain assessment and management</b>					
Pain scored	Yes (?/10)	No	n/a	other	
Pain managed according to score	Yes	No Under-dosed Over-dosed Delay.....hr	At home	Declined	allergy
<b>Potential Neutropenic sepsis patients</b>					
Were they identified at triage?	Yes	No	Don't know	n/a	
Were they given high priority (orange)	Yes	No	Don't know	n/a	
Did they have wcc measured within 1hr	Yes	No	Don't know	n/a	
Did they receive antibiotics in 1hr	Yes	No	Don't know	n/a	

### Appendix 11 - Data extraction table – triage dataset

Microsoft Excel© spreadsheet used to record data from the triage records. Data in columns A, B, M, N, O & P was from the original PAS patient dataset. All other data was extracted by the researcher from each ED clinical record

A	B	C	D	E	F	G	H	I	J	K
Attendance date & time	District Number	Time of arrival in bandings	Triage Nurse	Triage Chart	Right chart	Correct discriminator	Correct priority	Triage Priority 1-5	Pain Score Y/N	Analgesia matches score
01/07/2009 00:44										
01/07/2009 05:08										

continued	L	M	N	O	P	Q	R	S
	Stream	Age	Gender	Mode Of Arrival	ED ID	Intervention	Age range	Month
					09/041713			
					09/041724			

## Appendix 12 - Coding values – triage dataset

Column	Data analysed	Code
C	Time of arrival four hourly bandings	08:00-11:59 = 1 12:00-15:59 = 2 16:00-19:59 = 3 20:00-23:59 = 4 00:00-07:59 = 5
D	Triage Nurse experience	missing = 0 (not recorded or illegible) <3 years = 1 3-5 years = 2 6-10 years = 3 11yrs + = 4
E	Triage Chart	1-50 (see Appendix 13) 51 = missing
F	Correct Chart	Yes = 1                      No = 0
G	Correct discriminator	Yes = 1 No = 0 (including; missing or made up)
H	Correct Priority	Yes = 1 No = 0 (including missing)
I	Priority	Red = 1 Orange = 2 Yellow = 3 Green = 4 Blue = 5 Missing = 60
J	Pain score	Yes = 1                      No = 0
K	Analgesia given matches score	Yes = 1                      No = 0
L	Stream	Minors = 1                      Majors = 2
M	Age	Number
N	Gender	Male = 0                      Female = 1
O	Mode of arrival	Ambulance = 1                      Non-Ambulance = 0
P	ED ID	Number
Q	Intervention	Pre-eTriage = 0                      Post-eTriage = 1
R	Age ranges	0-15yrs = 1 16-34yrs = 2 35-59yrs = 3 60-75yrs = 4 >75yrs = 5
S	Pain Score	0 = no pain 1-3 mild pain 4-6 moderate pain 7-10 severe pain 11 = missing (not scored or n/a)
T	Month	April 2009 = 1 July 2009 = 2 October 2009 = 3 January 2010 = 4 April 2011 = 5 July 2011 = 6 October 2011 = 7 January 2012 = 8



### Appendix 13 - Triage charts

Column E (from Appendix 12)	Code allocated
Abdominal pain in adults	1
Abdominal pain in children	2
Abscesses and local infections	3
Allergy	4
Apparently drunk	5
Assault	6
Asthma	7
Back pain	8
Behaving strangely	9
Bites and stings	10
Burns and scalds	11
Chest pain	12
Collapsed adult	13
Crying baby	14
Dental problems	15
Diabetes	16
Diarrhoea and vomiting	17
Ear problems	18
Exposure to chemicals	19
Eye problems	20
Facial problems	21
Falls	22
Fits	23
Foreign body	24
GI bleeding	25
Headache	26
Head Injury	27
Irritable child	28
Limb problems	29
Limping child	30
Major Trauma	31
Mental Illness	32
Neck pain	33
Overdose and poisoning	34
Palpitations	35
Pregnancy	36
PV bleeding	37
Rashes	38
Self Harm	39
Sexually acquired infection	40
Shortness of breath in adults	41
Shortness of breath in children	42
Sore throat	43
Testicular pain	44
Torso Injury	45
Unwell adult	46
Unwell child	47
Urinary problems	48
Worried parent	49
Wounds	50

**Appendix 14 – Data extraction table – neutropenic sepsis dataset.**

Microsoft Excel© spreadsheet used to record data from the neutropenic sepsis cohort. Date in columns F, G, H, J & M was from the original PAS patient dataset. All other data was extracted from the ED clinical record or the haematology database

A	B	C	D	E	F	G	H	I	J	K
Pt ID	On chemotherapy	Triage priority 2	Time of FBC	Time of antibiotics	Time of attendance	Date of attendance	Age	Age range	Gender	Neutrophil count

L	M	N
Intervention	Mode of arrival	Early warning score

### Appendix 15 - Coding Values – neutropenic sepsis dataset

Column	Data analysed	Code
A	Pt ID	n/a
B	On chemotherapy	Yes = 1 No = 0
C	Triage priority 2	Yes = 1 No = 0
D	Time of FBC	<30 minutes = 1 31-60 minutes = 2 >60 minutes = 3 Before ED = 60
E	Time of antibiotics	<1hr = 1 1-2hrs = 2 2-3hrs = 3 3-4 hrs = 4 4-5hrs = 5 5-6hrs = 6
F	Time of attendance	24hr clock
G	Date of attendance	Date/month/year
H	Age	In years
I	Age range	0-15yrs = 1 16-34yrs = 2 35-59yrs = 3 60-75yrs = 4 >75yrs = 5
J	Gender	Male = 0 Female = 1
K	Neutrophil count	Laboratory assigned figure
L	Intervention	Pre-eTriage = 1 Post triage = 2
M	Time of arrival (in four hourly bandings)	08:00-11:59 = 1 12:00-15:59 = 2 16:00-19:59 = 3 20:00-23:59 = 4 00:00-07:59 = 5
N	Mode of arrival	Ambulance = 1 Non-Ambulance = 2
O	Early warning score	Score between 0-12

## Appendix 16 Email National Research Ethics Service 14/1/11

Your query was reviewed by our Queries Line Advisers.

Our leaflet “Defining Research”, which explains how we differentiate research from other activities, is published at:

<http://www.nres.npsa.nhs.uk/rec-community/guidance/#researchoraudit>

Based on the information you provided, our advice is that the project is not considered to be research according to this guidance. It would appear to be **service evaluation** and therefore it does not require ethical review by a NHS Research Ethics Committee.

If you are undertaking the project within the NHS, you should check with the relevant NHS care organisation(s) what other review arrangements or sources of advice apply to projects of this type. Guidance may be available from the clinical governance office.

Although ethical review by a NHS REC is not necessary in this case, all types of study involving human participants should be conducted in accordance with basic ethical principles such as informed consent and respect for the confidentiality of participants. When processing identifiable data there are also legal requirements under the Data Protection Act 2000. When undertaking an audit or service/therapy evaluation, the investigator and his/her team are responsible for considering the ethics of their project with advice from within their organisation. University projects may require approval by the university ethics committee.

This response should not be interpreted as giving a form of ethical approval or any endorsement of the project, but it may be provided to a journal or other body as evidence that ethical approval is not required under NHS research governance arrangements.

However, if you, your sponsor/funder or any NHS organisation feel that the project should be managed as research and/or that ethical review by a NHS REC is essential, please write setting out your reasons and we will be pleased to consider further.

Where NHS organisations have clarified that a project is not to be managed as research, the Research Governance Framework states that it should not be presented as research within the NHS.

If you have received advice on the same or a similar matter from a different source (for example directly from a Research Ethics Committee (REC) or from an NHS R&D department), it would be helpful if you could share the initial query and response received if then seeking additional advice through the NRES Queries service.

However, if you have been asked to follow a particular course of action by a REC as part of a provisional or conditional opinion, then the REC requirements are mandatory to the opinion, unless specifically revised by that REC. Should you wish to query the REC requirements, this should either be through contacting the REC direct or, alternatively, the relevant local operational manager.

Regards

Queries Line  
National Research Ethics Service  
National Patient Safety Agency  
4-8 Maple Street  
London

W1T 5HD

The NRES Queries Line is an email based service that provides advice from NRES senior management including operations managers based in our regional offices throughout England. Providing your query in an email helps us to quickly direct your enquiry to the most appropriate member of our team who can provide you with accurate written response. It also enables us to monitor the quality and timeliness of the advice given by NRES to ensure we can give you the best service possible, as well as use queries to continue to improve and to develop our processes.

Website: [www.nres.npsa.nhs.uk](http://www.nres.npsa.nhs.uk)

Email: [queries@nres.npsa.nhs.uk](mailto:queries@nres.npsa.nhs.uk)

Ref: 04/02

## References

- Advanced Life Support Group. (n.d.). Manchester Triage Retrieved 26 October, 2013, from <http://www.alsg.org/uk/MTS>
- American College of Surgeons. (2014). American College of Surgeons. Trauma Programs Retrieved 15 March, 2014, from <http://www.facs.org/trauma/tsepc/index.html>
- An-Wen, C., & Douglas, G. A. (2005). Identifying outcome reporting bias in randomised trials on PubMed: review of publications and survey of authors. *British Medical Journal*, 330.
- Andersson, A., Omberg, M., & Svedlund, M. (2006). Triage in the emergency department - a qualitative study of the factors which nurses consider when making decisions. *Nursing In Critical Care*, 11(3), 136-145.
- Appleby, J., Boyle, S., Devlin, N., Harley, M., Harrison, A., & Thorlby, R. (2005). Do English NHS waiting time targets distort treatment priorities in orthopaedic surgery? [10.1258/1355819054339022]. *Journal of Health Service Research and Policy*, 10, 167-172.
- Appleby, J., Humphreies, R., Thompson, J., & Galea, A. (2013). How is the health and social care system performing? Quarterly monitoring report Retrieved 22 July, 2013, from [http://www.kingsfund.org.uk/sites/files/kf/field/field\\_publication\\_file/quarterly-monitoring-report-kingsfund-jun13.pdf](http://www.kingsfund.org.uk/sites/files/kf/field/field_publication_file/quarterly-monitoring-report-kingsfund-jun13.pdf)
- Argyrous, G. (2007). Statistical Methods for Health Data Analysis. In M. Saks & J. Allsop (Eds.), *Researching Health. Qualitative, Quantitative and Mixed Methods*. London: Sage.
- Armstrong, P. A., White, A. L., & Thakore, S. (2008). Senior house officers and foundation year doctors in emergency medicine: do they perform equally? A prospective observational study. *Emergency Medicine Journal*, 25(11), 725-727. doi: 10.1136/emj.2008.059154
- Aronsky, D., Chan, K., J., & Haug, P., J. (2001). Evaluation of a computerised diagnostic decision support system for patients with pneumonia. *Journal of the American Medical Informatics Association*, 8(5), 473-485.
- Asaro, P. V., Sheldahl, A. L., & Char, D. M. (2006). Embedded guideline information without patient specificity in a commercial emergency department computerized order-entry system. *Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine*, 13(4), 452-458.
- Augestad, K., Berntsen, G., Lassen, K., Bellika, J. G., Wootton, R., & Lindsetmo, R. O. (2012). Standards for reporting randomized controlled trials in medical informatics: a systematic review of CONSORT adherence in RCTs on clinical decision

- support. *Journal of the American Medical Informatics Association*, 19(1), 13-21.
- Banning, M. (2008). A review of clinical decision making: models and current research. *Journal of Clinical Nursing*, 17(2), 187-195.
- Barnett, A. G., van der Pols, J. C., & Dobson, A. J. (2005). Regression to the mean: what it is and how to deal with it. *International Journal of Epidemiology*, 34(1), 215-220.
- Bates, D., & Gawande, A. (2003). Improving Safety with Information Technology. *New England Journal of Medicine*, 348(25), 2526-2534. doi: 10.1056/NEJMsa020847
- Bates, D., Kuperman, G., Wang, S., Gandhi, T., Kittler, A., Volk, L., Spurr, C., Khorasani, R., Tanasijevic, M., & Middleton, B. (2003). Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *Journal of the American Medical Informatics Association*, 10(6), 523-530. doi: <http://dx.doi.org/10.1197/jamia.M1370>
- BBC News. (2013a). Major problems for NHS 111 service Retrieved 2 October, 2013, from <http://www.bbc.co.uk/news/health-23152697>
- BBC News. (2013b). Q&A: NHS 111 Retrieved 2 October, 2013, from <http://www.bbc.co.uk/news/health-22370621>
- Belcher, J. (2001). An overview of time series analysis. *Nurse Researcher*, 9(1), 26-40.
- Bender, M. (n.d ). Interrupted Time Series Research Design Retrieved 11 November, 2012, from <http://www.pcori.org/search/?q=time+series>
- Bender, M., Connelly, C. D., Glaser, D., & Brown, C. (2012). Clinical Nurse Leader Impact on Microsystem Care Quality. *Nursing Research*, 61(5), 326-332.
- Benner, P. (1984). *From Novice to Expert: Excellence and power in clinical nursing practice*. New York: Prentice Hall.
- Benner, P., & Tanner, C. (1987). How expert nurses use intuition. *The American Journal of Nursing*, 87(1), 23-34.
- Bennett, P. (2012). Nursing quality indicators: The next step in enhancing quality in emergency care. *International Emergency Nursing*, 20(3), 179-186. doi: 10.1016/j.ienj.2012.04.001
- Bergman, C. L. (2012). Emergency Nurses' Perceived Barriers to Demonstrating Caring When Managing Adult Patients' Pain. *Journal of Emergency Nursing*, 38(3), 218-225. doi: <http://dx.doi.org/10.1016/j.ien.2010.09.017>
- Bevan, G., & Hood, C. (2006). Have targets improved performance in the English NHS? *British Medical Journal*, 332, 419e422.
- Bhakta, H. C., & Marco, C. A. (2014). Pain Management: Association with

Patient Satisfaction among Emergency Department Patients. *The Journal Of Emergency Medicine*, 46(4), 456-464. doi:  
<http://dx.doi.org/10.1016/j.jemermed.2013.04.018>

Biglan, A., Ary, D., & Wagenaar, A. (2000). The value of interrupted time-series experiments for community intervention research. . *Prevention Science*, 1(1), 31-49.

Blaber, A. (2012). *Foundations for Paramedic Practice: A theoretical perspective* (2nd ed.). Oxford: Open University Press.

Black, A. D., Car, J., Pagliari, C., Anandan, C., Cresswell, K., Bokun, T., McKinstry, B., Procter, R., Majeed, A., & Sheikh, A. (2011). The Impact of eHealth on the Quality and Safety of Health Care: A Systematic Overview. *PLoS Medicine*, 8(1), e1000387. doi: 10.1371/journal.pmed.1000387

Bland, J. M., & Altman, D. G. (1994). Statistics Notes: Some examples of regression towards the mean. *British Medical Journal*, 309.

Body, R., & Foex, B. A. (2012). Optimising well-being: is it the pain or the hurt that matters? *Emergency Medicine Journal*, 29(2), 91-94.

Bond, C. M., Djogovic, D., Villa-Roel, C., Bullard, M. J., Meurer, D. P., & Rowe, B. H. (2013). Pilot Study Comparing Sepsis Management with and without Electronic Clinical Practice Guidelines in an Academic Emergency Department. *The Journal Of Emergency Medicine*, 44(3), 698-708. doi:  
<http://dx.doi.org/10.1016/j.jemermed.2012.08.025>

Booth, A. J., Harrison, C. J., Gardener, G. J., & Gray, A. J. (1992). Waiting times and patient satisfaction in the accident and emergency department. [10.1136/emj.9.2.162]. *Archives of Emergency Medicine*, 9, 162-168.

Boyd, R. J., & Stuart, P. (2005). The efficacy of structured assessment and analgesia provision in the paediatric emergency department. *Emergency Medicine Journal*, 22(1), 30-32.

Brennan, F., Carr, D., & Cousin, M. (2007). Pain management: a fundamental human right. *Anesthesia and Analgesia*, 105(1), 205-210.

British Medical Association. (2013a). GPs implore government to delay NHS 111 Retrieved 2 November, 2013, from <http://bma.org.uk/news-views-analysis/news/2013/march/gps-implore-government-to-delay-nhs-111>

British Medical Association. (2013b). NHS 111 delayed in 24 regions after BMA warning Retrieved 12 November, 2013, from <http://bma.org.uk/news-views-analysis/news/2013/april/nhs-111-delayed-in-24-regions>

Britton, D. J., Bloch, R. B., Strout, T. D., & Baumann, M. R. (2013). Impact of a computerized order set on adherence to centers for disease control guidelines for



the treatment of victims of sexual assault. *Journal of Emergency Medicine*, 44(2), 528-535.

Brockopp, D., Downey, E., Powers, P., Vanderveer, B., Warden, S., Ryan, P., & Saleh, U. (2004). Nurses clinical decision-making regarding the management of pain. *Accident And Emergency Nursing*, 12(4), 224-229. doi: <http://dx.doi.org/10.1016/j.aaen.2004.01.008>

Broom, A., & Willis, E. (2007). Competing paradigms and health research. In M. Saks & J. Allsop (Eds.), *Researching Health. Qualitative, Quantitative and Mixed Methods*. London: Sage.

Brown, C., & Lilford, R. (2008). Evaluating service delivery interventions to enhance patient safety. *British Medical Journal*, 337(dec17 1), a2764-a2764. doi: 10.1136/bmj.a2764

Bruce, N., Pope, D., & Stanistreet, D. (2008). *Quantitative Methods for Health Research. A practical interactive guide to Epidemiology and Statistics*. New York: Wiley.

Bryan, C., & Boren, S. A. (2008). The use and effectiveness of electronic clinical decision support tools in the ambulatory/primary care setting: a systematic review of the literature. *Informatics In Primary Care*, 16(2), 79-91.

Buising, K. L., Thursky, K. A., Black, J. F., MacGregor, L., Street, A. C., Kennedy, M. P., & Brown, G. V. (2008). Improving antibiotic prescribing for adults with community acquired pneumonia: Does a computerised decision support system achieve more than academic detailing alone? - A time series analysis. *BMC Medical Informatics and Decision Making*, 8, 35. doi: 10.1186/1472-6947-8-35

Burt, C. W., & Hing, E. (2005). Use of computerized clinical support systems in medical settings: United States, 2001-03. *Advance Data*(353), 1-8.

Campbell, J., Britten, N., Green, C., Holt, T., Lattimer, V., Richards, S., Richards, D., Salisbury, C., Taylor, R., & Fletcher, E. (2013). The effectiveness and cost-effectiveness of telephone triage of patients requesting same day consultations in general practice: study protocol for a cluster randomised controlled trial comparing nurse-led and GP-led management systems (ESTEEM). *Trials*, 14, 4-4. doi: 10.1186/1745-6215-14-4

Campbell, M., Fitzpatrick, R., Haines, A., Kinmonth, A. L., Sandercock, P., Spiegelhalter, D., & Tyrer, P. (2000). Framework for design and evaluation of complex interventions to improve health. *British Medical Journal*, 321, 694-696.

Carman, M. J., Phipps, J., Raley, J., Li, S., & Thornlow, D. (2011). Use of a clinical decision support tool to improve guideline adherence for the treatment of methicillin-resistant staphylococcus aureus: Skin and soft tissue infections. *Advanced Emergency Nursing Journal*, 33(3), 252- 266.

- Carnevali, D. L., Mitchell, P. H., Woods, N. F., & Tanner, C. A. (1984). *Diagnostic reasoning in nursing*. Philadelphia: Lippincott.
- Carr, B. G., Kaye, A. J., Wiebe, D. J., Gracias, V. H., Schwab, C. W., & Reilly, P. M. (2007). Emergency Department Length of Stay: a Major Risk Factor for Pneumonia in Intubated Blunt Trauma Patients. *Journal of Trauma and Acute Care Surgery*, 63(1).
- Carroll, A. E., Anand, V., & Downs, S. M. (2012). Understanding why clinicians answer or ignore clinical decision support prompts. *Applied Clinical Informatics*, 3(3), 309-317. doi: 10.4338/aci-2012-04-ra-0013
- Carter, A. J., Davis, K. A., Evan, L. V., & Cone, D. C. (2009). Information loss in emergency medical services. *Prehospital Emergency Care*, 13(3), 280-285.
- Cavendish, C. (2013). *The Cavendish Review. An Independent Review into Healthcare Assistant and Support Workers in the NHS and social care settings* London: DH  
Retrieved from  
[https://http://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/236212/Cavendish\\_Review.pdf](https://http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/236212/Cavendish_Review.pdf).
- CEM. (2010a). College of Emergency Medicine Clinical Audits Executive Summary Retrieved 3 July, 2013, from <http://www.collemergencymed.ac.uk/Shop-Floor/Clinical Audit/Previous Audits/>
- CEM. (2010b). Guideline for the management of pain in adults Retrieved 2 June, 2013, from <http://www.collemergencymed.ac.uk/Shop-Floor/Clinical Guidelines/College Guidelines/>
- CEM. (2010c). Guideline for the management of pain in children Retrieved 3 June, 2013, from <http://www.collemergencymed.ac.uk/Shop-Floor/Clinical Guidelines/College Guidelines/>
- CEM. (2011). Triage Position Statement Retrieved from College of Emergency Medicine website: <http://secure.collemergencymed.ac.uk/Shop-Floor/Clinical Guidelines/College Guidelines>
- CEM. (2013a). Clinical Standards in the Emergency Department Retrieved 23 November, 2013, from <http://www.collemergencymed.ac.uk/Shop-Floor/Clinical Standards/default.asp>
- CEM. (2013b). The drive for quality. How to achieve safe, sustainable care in our Emergency Departments. Retrieved from <http://www.collemergencymed.ac.uk/Shop-Floor/Professional Standards/Quality in the Emergency Department/>
- CEM. (n.d.). Safety in your ED Retrieved 12 March, 2014, from <http://www.collemergencymed.ac.uk/Shop-Floor/Safer Care/Safety in your ED/>
- Centre for Maternal and Child Enquires. (2011). *Saving Mothers' Lives. Reviewing*

*maternal death to make motherhood safer: 2006-2008*. London: Wiley-Blackwell  
Retrieved from <http://www.hqip.org.uk/assets/NCAPOP-Library/CMACE-Reports/6.-March-2011-Saving-Mothers-Lives-reviewing-maternal-deaths-to-make-motherhood-safer-2006-2008.pdf>.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., Morton, S. C., & Shekelle, P. G. (2006). Systematic Review: Impact of Health Information Technology on Quality, Efficiency, and Costs of Medical Care. *Annals of Internal Medicine*, 144(10), 742-752. doi: 10.7326/0003-4819-144-10-200605160-00125

Chuang, J.-H., Hripcsak, G., & Heitjan, D. F. (2002). Design and analysis of controlled trial in naturally clustered environments. Implications for medical informatics. *Journal of the American Medical Informatics Association*, 9, 230-238.

Cioffi, J. (1999). Triage decision making: Educational strategies. *Accident And Emergency Nursing*, 7(2), 106-111. doi: [http://dx.doi.org/10.1016/S0965-2302\(99\)80031-9](http://dx.doi.org/10.1016/S0965-2302(99)80031-9)

Clancy, K. (2007). Experiences of a novice researcher. *Nurse Researcher*, 14(4), 27-38. doi: 10.7748/nr2007.07.14.4.27.c6041

Clwyd, A., & Hart, T. (2013). *A Review of the NHS Hospitals Complaints System. Putting Patients Back in the Picture*. London: DH Retrieved from [https://http://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/255615/NHS\\_complaints\\_accessible.pdf](https://http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255615/NHS_complaints_accessible.pdf).

Cochrane. (n.d.). Glossary Retrieved 1 February 2014, from <http://www.cochrane.org/glossary/5-lettera>

Cochrane Childhood Cancer Group. (n.d.). Non-Randomised Controlled Study (NRS) Designs Retrieved 19 November, 2013, from <http://ccg.cochrane.org/non-randomised-controlled-study-nrs-designs>

Cone, K. J., & Murray, R. (2002). Characteristics, insights, decision making, and preparation of ED triage nurses. *Journal of Emergency Nursing*, 28(5), 401-406. doi: <http://dx.doi.org/10.1067/men.2002.127513>

Considine, J., Botti, M., & Thomas, S. (2007). Do knowledge and experience have specific roles in triage decision-making? *Academic emergency medicine : Official Journal of the Society for Academic Emergency Medicine*, 14(8), 722-726. doi: 10.1197/j.aem.2007.04.015

Considine, J., Ung, L., & Thomas, S. (2000). Triage nurses decisions using the National Triage Scale for Australian emergency departments. *Accident And Emergency Nursing*, 8(4), 201-209. doi: <http://dx.doi.org/10.1054/aaen.2000.0166>

Considine, J., Ung, L., & Thomas, S. (2001). Clinical Decisions using the National Triage Scale: how important is postgraduate education. *Accident And Emergency Nursing*, 9(2), 101-108. doi:

<http://dx.doi.org/10.1054/aaen.2000.0209>

Cooke, M., Fisher, J., Dale, J., McLeod, E., Szczepura, A., Walley, P., & Wilson, S. (2004). Reducing Attendances and Waits in Emergency Departments. A systematic review of present innovations. Report to the National Co-ordinating Centre for NHS Service Delivery and Organisation R & D (NCCSDO). Retrieved from [http://wrap-test.warwick.ac.uk/134/1/WRAP\\_Szczepura\\_29-final-report.pdf](http://wrap-test.warwick.ac.uk/134/1/WRAP_Szczepura_29-final-report.pdf)

Cooke, M. W., & Jinks, S. (1999). Does the Manchester triage system detect the critically ill? *Journal of Accident & Emergency Medicine*, 16(3), 179-181.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. *British Medical Journal*, 337.

Crouch, R., & Dale, J. (1997). Decision support for telephone advice. *Journal of Accident & Emergency Medicine*, 14(3), 201-202. doi: 10.1136/emj.14.3.201-c

Crouch, R., & Marrow, J. (1996). Towards a UK Triage Scale. *Emergency Nurse*, 4(3), 4-5.

Cummings, J. (2013). *How to ensure the right people, with the right skills, are in the right place at the right time. A guide to nursing midwifery and care staffing capacity and capability*. London: DH Retrieved from <http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-how-to-guid.pdf>.

Dale, J., Green, J., Reid, F., Glucksman, E., & Higgs, R. (1995). Primary care in the accident and emergency department: II. comparison of general practitioners and hospital doctors. *British Medical Journal*, 311.

Dale, J., Higgins, J., Williams, S., Foster, T., Snooks, H., Crouch, R., Hartley-Sharpe, C., Glucksman, E., Hooper, R., & George, S. (2003). Computer assisted assessment and advice for "non-serious" 999 ambulance service callers: the potential impact on ambulance despatch. *Emergency Medicine Journal*, 20(2), 178-183.

Darzi, A. (2008). *High Quality Care for All*. London: DH.

Davis, P., & Scott, A. (2007). Health Research Sampling Methods In M. Saks & J. Allsop (Eds.), *Researching Health. Qualitative, Quantitative and Mixed Methods*. Los Angeles: Sage.

Dawood, M., Dobson, A., & Banerjee, A. (2011). the treatment of older patients in emergency departments. *Emergency Nurse*, 19(7), 18-19.

Day, F., Hoang, L. P., Ouk, S., Nagda, S., & Schriger, D. L. (1995). The impact of a guideline-driven computer charting system on the emergency care of patients with acute low back pain. *Proceedings The Annual Symposium On Computer Applications In Medical Care.*, 576-580.

de Dombal, F., Leaper, D., Staniland, J., McCann, A., & Horrocks, J. (1972).

Computer-aided Diagnosis of Acute Abdominal Pain. [10.1136/bmj.2.5804.9]. *British Medical Journal*, 2(5804), 9-13.

Deeks, J., Dinnes, J., D'Amico, A., Sowden, A., Sakarovitch, B., Song, F., Petticrew, M., & Altman, D. (2003). Evaluating non-randomised intervention studies. *Health Technology Assessment* 7(27).

Dexheimer, J. W., Abramo, T. J., Arnold, D. H., Johnson, K. B., Shyr, Y., Ye, F., Fan, K.-H., Patel, N., & Aronsky, D. (2013). An asthma management system in a pediatric emergency department. *International Journal of Medical Informatics*, 82(4), 230-238. doi: 10.1016/j.ijmedinf.2012.11.006

Dexheimer, J. W., Talbot, T. R., 3rd, Ye, F., Shyr, Y., Jones, I., Gregg, W. M., & Aronsky, D. (2011). A computerized pneumococcal vaccination reminder system in the adult emergency department. *Vaccine*, 29(40), 7035-7041. doi: 10.1016/j.vaccine.2011.07.032

DH. (1991). *The Patient's Charter*. London: Department of Health.

DH. (1999). *Making a Difference. Strengthening the nursing, midwifery and health visiting contribution to health and healthcare*. London: Department of Health  
Retrieved from  
[http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod\\_consum\\_dh/groups/dh\\_digitalassets/@dh/@en/documents/digitalasset/dh\\_4074704.pdf](http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4074704.pdf).

DH. (2000). *The NHS Plan: A plan for investment. A plan for reform*. London: Department of Health.

DH. (2001). *Reforming Emergency Care*. London: Department of Health.

DH. (2004). *Transforming Emergency Care in England*. London: Department of Health.

DH. (2005). Modernising Medical Careers - the new curriculum for the foundation years in postgraduate education and training Retrieved 6 November, 2013, from  
[http://webarchive.nationalarchives.gov.uk/+www.dh.gov.uk/en/Aboutus/MinistersandDepartmentLeaders/ChiefMedicalOfficer/Features/FeaturesArchive/DH\\_4107830](http://webarchive.nationalarchives.gov.uk/+www.dh.gov.uk/en/Aboutus/MinistersandDepartmentLeaders/ChiefMedicalOfficer/Features/FeaturesArchive/DH_4107830)

DH. (2007). Emergency Services Collaborative Retrieved 11 February, 2012, from  
[http://webarchive.nationalarchives.gov.uk/+www.dh.gov.uk/en/Healthcare/IntegratedCare/Changeagentteam/DH\\_4049385](http://webarchive.nationalarchives.gov.uk/+www.dh.gov.uk/en/Healthcare/IntegratedCare/Changeagentteam/DH_4049385)

DH. (2010a). *A&E Clinical Quality indicators. Implementation Guidance*. London: Department of Health.

DH. (2010b). *Equity and Excellence: liberating the NHS*. London: Department of Health.

- DH. (2010c). *NHS Costing Manual 2009/10 February 2010*. London: Department of Health.
- DH. (2012). *The power of information: Putting all of us in control of the health and care information we need*. London: Department of Health.
- DH. (2013a). *The Government Response to the House of Commons Health Select Committee Third Report of Sessions 2013-14: After Francis: making a difference*. London: Department of Health Retrieved from [https://http://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/259650/34661\\_Cm\\_8755\\_Accessible.pdf](https://http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/259650/34661_Cm_8755_Accessible.pdf).
- DH. (2013b). *Handbook to the NHS Constitution*. London: Department of Health.
- DH. (2014). Emergency and Urgent Care Services. Major Trauma Services Retrieved 15 March, 2014, from <http://www.nhs.uk/NHSEngland/AboutNHSservices/Emergencyandurgentcareservices/Pages/Majortraumaservices.aspx>
- DH. (n.d.-a). The digital challenge. How a paperless NHS will improve services Retrieved 4 April, 2014, from <http://digitalchallenge.dh.gov.uk>
- DH. (n.d.-b). Hospital Activity Statistics A&E attendance data Retrieved 4 May, 2010, from [http://www.performance.doh.gov.uk/hospitalactivity/data\\_requests/a\\_and\\_e\\_attendances.htm](http://www.performance.doh.gov.uk/hospitalactivity/data_requests/a_and_e_attendances.htm)
- DH. (n.d.-c). NHS Connecting for Health Retrieved 2 March, 2014, from <http://www.connectingforhealth.nhs.uk>
- DH. (n.d.-d). NHSmail/NHSmail 2 Retrieved 2 March, 2014, from <http://www.connectingforhealth.nhs.uk/systemsandservices/nhsmail/>
- DH. (n.d.-e). What does PACS mean for me? Retrieved 2 March, 2014, from <http://www.connectingforhealth.nhs.uk/systemsandservices/pacs/learn/me>
- Dijkstra, R., Wensing, M., Thomas, R., Akkermans, R., Braspenning, J., Grimshaw, J., & Grol, R. (2006). The relationship between organisational characteristics and the effects of clinical guidelines on medical performance in hospitals, a meta-analysis. [10.1186/1472-6963-6-53]. *BMC Health Services Research*, 6(1), 53.
- Dong, S. L., Bullard, M. J., Meurer, D. P., Colman, I., Blitz, S., Holroyd, B. R., & Rowe, B. H. (2005). Emergency Triage: Comparing a Novel Computer Program with Standard Triage. *Academic Emergency Medicine*, 12, 502-507.
- Dowding, D., Mitchell, N., Randell, R., Foster, R., Lattimer, V., & Thompson, C. (2009a). Nurses' use of computerised clinical decision support systems: a case site analysis. *Journal of Clinical Nursing*, 18(8), 1159-1167. doi: 10.1111/j.1365-2702.2008.02607.x

Dowding, D., Randell, R., Mitchell, N., Foster, R., Thompson, C., Lattimer, V., & Cullum, N. (2009b). Experience and nurses use of computerised decision support systems. *Studies In Health Technology And Informatics*, 146, 506-510.

Dowding, D., Turley, M., & Garrido, T. (2012). The impact of an electronic health record on nurse sensitive patient outcomes: an interrupted time series analysis. *Journal of the American Medical Informatics Association*, 19(4), 615-620.

Dr Foster Intelligence. (n.d.). Strengthen your weekend care. Retrieved 11 August, 2013, from <http://myhospitalguide.drfoosterintelligence.co.uk/-/weekend-care>

Drescher, F. S., Chandrika, S., Weir, I. D., Weintraub, J. T., Berman, L., Lee, R., Van Buskirk, P. D., Wang, Y., Adewunmi, A., & Fine, J. M. (2011). Effectiveness and acceptability of a computerized decision support system using modified Wells criteria for evaluation of suspected pulmonary embolism. *Annals of Emergency Medicine*, 57(6), 613-621. doi: 10.1016/j.annemergmed.2010.09.018

Ducharme, J., Tanabe, P., Homel, P., Miner, J. R., Chang, A. K., Lee, J., & Todd, K. H. (2008). The influence of triage systems and triage scores on timeliness of ED analgesic administration. *The American Journal of Emergency Medicine*, 26(8), 867-873. doi: <http://dx.doi.org/10.1016/j.ajem.2007.11.020>

Eccles, M., Grimshaw, J., Campbell, M., & Ramsay, C. (2003). Research designs for studies evaluating the effectiveness of change and improvement strategies. *Quality and Safety in Health Care*, 12(1), 47-52.

Edwards, B. (2003). *The process of Nurse Triage: A grounded theory exploration*. PhD, South Bank University.

Edwards, B. (2007). Walking in, Initial visualisation and assessment at triage. *Accident And Emergency Nursing*, 15(2), 73-78. doi: <http://dx.doi.org/10.1016/j.aaen.2006.12.008>

Elliott, H., & Popay, J. (2000). How are policy makers using evidence? Models of research utilisation and local NHS policy making. *Journal of Epidemiology and Community Health*, 54(6), 461-468.

Elstein, A. S., Shulman, L. S., & Sprafka, S. A. (1978). *Medicial problem solving: An analysis of clinical reasoning*. Cambridge: Harvard University Press.

England, E. (2005). How interrupted time series analysis can evaluate guideline implementation *The Pharmaceutical Journal*, 275, 344-347.

EPOC. (2012). Cochrane Effective Practice and Organisation of Care Group Retrieved 12 March, 2013, from <http://epoc.cochrane.org>

EPOC. (2013a). Suggested risk of bias criteria for EPOC reviews. Retrieved from [http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/14\\_Suggested\\_risk\\_of\\_bias\\_criteria\\_for\\_EPOC\\_reviews\\_2013\\_08\\_12.pdf](http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/14_Suggested_risk_of_bias_criteria_for_EPOC_reviews_2013_08_12.pdf)



- EPOC. (2013b). What study designs should be included in an EPOC review and what should they be called? Retrieved from [http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/05\\_What\\_study\\_designs\\_should\\_be\\_included\\_in\\_an\\_EPOC\\_review\\_2013\\_08\\_12.pdf](http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/05_What_study_designs_should_be_included_in_an_EPOC_review_2013_08_12.pdf)
- Eslami, S., Abu-Hanna, A., & de Keizer, N. F. (2007). Evaluation of outpatient computerized physician medication order entry systems: a systematic review. *Journal Of The American Medical Informatics Association*, 14(4), 400-406.
- Evans, S. M., Murray, A., Patrick, I., Fitzgerald, M., Smith, S., Andrianopoulos, N., & Cmaeron, P. (2010). Assessing clinical handover between paramedics and the trauma team. *Injury*, 41(5), 460-464.
- Field, A. (2009). *Discovering Statistics using SPSS* (3rd ed.). Los Angeles: Sage.
- FitzGerald, G. (1990). *Emergency department triage: a thesis accepted for the degree of Doctor of Medicine*. University of Queensland. Brisbane.
- FitzGerald, G., Jelinek, G. A., Scott, D., & Gerdtz, M. F. (2010). Emergency department triage revisited. *Emergency Medicine Journal*, 27(2), 86-92.
- Flodgren, G., & Oddgard-Jensen, J. (2013). Interrupted time series (ITS) analyses Retrieved 30 November, 2013, from [http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/21\\_Interrupted\\_time\\_series\\_analyses\\_2013\\_08\\_12.pdf](http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/21_Interrupted_time_series_analyses_2013_08_12.pdf)
- Fosnocht, D. E., & Swanson, E. R. (2007). Use of a triage pain protocol in the ED. *The American Journal of Emergency Medicine*, 25(7), 791-793. doi: <http://dx.doi.org/10.1016/j.ajem.2006.12.020>
- Francis, R. (2013). *Report of the Mid Staffordshire NHS Foundation Trust Public Enquiry*. London: The Stationary Office.
- Friedman, C., P., & Wyatt, J., C. (2010). *Evaluation Methods in Biomedical Informatics* (2nd ed.). New York: Springer.
- Fry, M., Bennetts, S., & Huckson, S. (2011). An Australian Audit of ED Pain Management Patterns. *Journal of Emergency Nursing*, 37(3), 269-274. doi: <http://dx.doi.org/10.1016/j.jen.2010.03.007>
- Funderburke, P. (2008). Exploring best practice for triage. *Journal Of Emergency Nursing*, 34(2), 180-182. doi: 10.1016/j.jen.2007.11.013
- Gallagher, M., Huddart, T., & Henderson, B. (1998). Telephone triage of acute illness by a practice nurse in general practice: outcomes of care. *British Journal of General Practice*, 48(429), 1141-1145.
- Gardner, F. (Ed.). (2006). *Using critical reflection in research and evaluation*. Maidenhead: Open University Press.



Garg, A. X., Adhikari, N., K.J. , McDonald, H., Rosas-Arellano, M., P., Devereaux, P., J., Sam, J., & Haynes, R., B. (2005). Effects of Computerised Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes. *The Journal of the American Medical Association*, 293(10), 1223-1238.

Geelhoed, G., & Geelhoed, E. (2008). Positive impact of increased number of emergency consultants. *Archives of Disease in Childhood*, 93(1), 62-64.

General Medical Council. (2013). Medical Education Frontline. A review of training in seven emergency departments. Retrieved from <http://www.gmc-uk.org>

George, G., Jell, C., & Todd, B. S. (2006). Effect of population ageing on emergency department speed and efficiency: a historical perspective from a district general hospital in the UK. *Emergency Medicine Journal*, 23(5), 379-383.

Georgiou, A., Prgomet, M., Markewycz, A., Adams, E., & Westbrook, J. I. (2011). The impact of computerized provider order entry systems on medical-imaging services: a systematic review. *Journal Of The American Medical Informatics Association*, 18(3), 335-340. doi: 10.1136/amiajnl-2010-000043

Georgiou, A., Prgomet, M., Paoloni, R., Creswick, N., Hordern, A., Walter, S., & Westbrook, J. (2013). The effect of computerized provider order entry systems on clinical care and work processes in emergency departments: a systematic review of the quantitative literature. *Annals of Emergency Medicine*, 61(6), 644-653.e616. doi: 10.1016/j.annemergmed.2013.01.028

Georgiou, A., Williamson, M., Westbrook, J. I., & Ray, S. (2007). The impact of computerised physician order entry systems on pathology services: a systematic review. *International Journal of Medical Informatics*, 76(7), 514-529.

Gerdtz, M., & Bucknall, T. K. (2007). Influence of task properties and subjectivity on consistency of triage: a simulation study. *Journal Of Advanced Nursing*, 58(2), 180-190.

Gerdtz, M., Chu, M., Collins, M., Considine, J., Crellin, D., Sands, N., Stewart, C., & Pollock, W. (2009). Factors influencing consistency of triage using the Australasian Triage Scale: implications for guideline development. *Emergency Medicine Australasia*, 21(4), 277-285. doi: 10.1111/j.1742-6723.2009.01197.x

Gibbs, M. A., Baumann, M. R., Lyden, J., Strout, T. D., & Knowles, D. (2012). Effect of the implementation of an electronic clinical decision support tool on adherence to joint commission pneumonia core measures in an academic emergency department. *Academic Emergency Medicine*, 19, S198-S199.

Goergen, S. K., Fong, C., Dalziel, K., & Fennessy, G. (2006). Can an evidence-based guideline reduce unnecessary imaging of road trauma patients with cervical spine injury in the emergency department? [Clinical Trial]. *Australasian radiology*, 50(6), 563-569. doi: 10.1111/j.1440-1673.2006.01655.x

- Gonzalez, E. R., Vanderheyden, B. A., Ornato, J. P., & Comstock, T. G. (1989). Computer-assisted optimization of aminophylline therapy in the emergency department. *The American Journal of Emergency Medicine*, 7(4), 395-401. doi: [http://dx.doi.org/10.1016/0735-6757\(89\)90046-6](http://dx.doi.org/10.1016/0735-6757(89)90046-6)
- Göransson, K., Ehrenberg, A., Marklund, B., & Ehnfors, M. (2006). Emergency department triage: is there a link between nurses' personal characteristics and accuracy in triage decisions? *Accident And Emergency Nursing*, 14(2), 83-88.
- Graber, M., Gordon, R., & Franklin, N. (2002). Reducing diagnostic errors in medicine: what's the goal? *Academic Medicine*, 77(10), 981-992.
- Graham, J. (2002). Adult patients' perceptions of pain management at triage: a small exploratory study. *Accident And Emergency Nursing*, 10(2), 78-86. doi: <http://dx.doi.org/10.1054/aaen.2001.0324>
- Graham, T., Kushniruk, A., Bullard, M., Holroyd, B., Meurer, D., & Rowe, B. (2008). How usability of a web-based clinical decision support system has the potential to contribute to adverse medical events. *American Medical Informatics Association. Annual Symposium Proceedings*, 257-261.
- Greenhalgh, T. (2010). *How to read a paper. The basics of evidence d based medicine* (4th ed.). London: BMJ Books.
- Griffey, R. T., Lo, H. G., Burdick, E., Keohane, C., & Bates, D. W. (2012). Guided medication dosing for elderly emergency patients using real-time, computerized decision support. *Journal Of The American Medical Informatics Association*, 19(1), 86-93. doi: 10.1136/amiajnl-2011-000124
- Grimshaw, J., Campbell, M., Eccles, M., & Steen, N. (2000). Experimental and quasi-experimental designs for evaluating guideline implementation strategies. *Family Practice*, 17(suppl 1), S11-S16.
- Grimshaw, J., Eccles, M., Lavis, J., Hill, S., & Squires, J. (2012). Knowledge translation of research findings. [10.1186/1748-5908-7-50]. *Implementation science*, 7(1), 50.
- Grimshaw, J., Thomas, R., MacLennan, G., Fraser, C., & Ramsay, C. (2004). Effectiveness and efficiency of guideline dissemination and implementation strategies. *Health Technology Assessment*, 8(6), 84. doi: 10.3310/hta8060
- Grimshaw, J., & Eccles, M. (2004). Is evidence-based implementation of evidence-based care possible? *Medical Journal of Australia*, 180(6 Suppl), S50-51.
- Grouse, A. I., Bishop, R. O., & Bannon, A. M. (2009). The Manchester Triage System provides good reliability in an Australian emergency department. *Emergency Medicine Journal*, 26(7), 484-486.
- Guttmann, A., Schull, M. J., Vermeulen, M., & Stukel, T. (2011). Association between waiting times and short term mortality and hospital admission after departure

from emergency department: population based cohort study from Ontario, Canada. *British Medical Journal*, 342.

Guyatt, G. H., Sackett, D. L., Sinclair, J. C., & et al. (1995). Users guides to the medical literature: IX. a method for grading health care recommendations. *Journal of the American Medical Association*, 274(22), 1800-1804. doi: 10.1001/jama.1995.03530220066035

Haji-Michael, P. (2010, 1 September 2013). Guidelines for the management of sepsis (including neutropenic sepsis). The Christie NHS Foundation Trust. Retrieved 1 September, 2013, from [http://www.christie.nhs.uk/media/194452/guidelines\\_for\\_the\\_management\\_of\\_sepsis.pdf](http://www.christie.nhs.uk/media/194452/guidelines_for_the_management_of_sepsis.pdf)

Hamm, R. M. (1988). Clinical intuition and clinical analysis: expertise and the cognitive continuum. In J. Dowie & A. S. Elstein (Eds.), *Professional judgement, A Readers in Clinical Decision Making* (pp. 78-105). Cambridge: Cambridge University Press.

Handel, D. A., Wears, R. L., Nathanson, L. A., & Pines, J. M. (2011). Using information technology to improve the quality and safety of emergency care. *Academic Emergency Medicine*, 18(6), e45-e51. doi: 10.1111/j.1553-2712.2011.01070.x

Harris, A. D., McGregor, J. C., Perencevich, E. N., Furuno, J. P., Zhu, J., Peterson, D. E., & Finkelstein, J. (2006). The use and interpretation of quasi-experimental studies in medical informatics. *Journal of the American Medical Informatics Association*, 13(1), 16-23. doi: 10.1197/jamia.M1749

Hassan, T., Walker, B., Harrison, M., & Rae, F. (2013). Stretched to the limit. A survey of Emergency Medicine consultants in the UK. Retrieved from <http://secure.collemergencymed.ac.uk>

Hawton, K., Bergen, H., Simkin, S., Brock, A., Griffiths, C., Romeri, E., Smith, K., Kapur, N., & Gunnell, D. (2009). Effect of withdrawal of co-proxamol on prescribing and deaths from drug poisoning in England and Wales: time series analysis *British Medical Journal*, 338. doi: doi:10.1136/bmj.b2270

Haynes, R. B. (2011). Computerised Clinical Decision Support Systems: How effective are they? Retrieved 17 March, 2012, from <http://www.implementationscience.com/series/CCDSS>

Haynes, R. B., & Wilczynski, N. L. (2010). Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: methods of a decision-maker-researcher partnership systematic review. *Implementation Science*, 5, 12. doi: 10.1186/1748-5908-5-12

Health Select Committee. (2013a). Health Select Committee written evidence from the College of Emergency Medicine (ES 07) Retrieved 12 October, 2103, from

<http://www.publications.parliament.uk/pa/cm201314/cmselect/cmhealth/171/171we06.htm>

Health Select Committee. (2013b). Health Select Committee. Improving A&E performance Retrieved 12 October 2013, from <http://www.publications.parliament.uk/pa/cm201314/cmselect/cmhealth/171/17108.htm> - n82

Heartfield, M. (2000). Research directions for specialist practice. *Accident And Emergency Nursing*, 8(4), 214-222. doi: <http://dx.doi.org/10.1054/aaen.2000.0159>

Hemens, B., Holbrook A, Tonkin M, Mackay, J., Weise-Kelly, L., Navarro T, Wilczynski N, & B, H. (2011). Computerised clinical decision support systems for drug prescribing and management: A decision-maker-researcher partnership systematic review. *Implementation Science*, 6(89), 1-17.

Herbst, C., Naumann, F., Kruse, E., Monsef, I., Bohlius, J., Schulz, H., & Engert, A. (2009). Prophylactic antibiotics or G-CSF for the prevention of infections and improvement of survival in cancer patients undergoing chemotherapy. *Cochrane Database of Systematic Reviews*, (1). Retrieved from <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD007107.pub2/abstract> doi:10.1002/14651858.CD007107.pub2

Higgins, J., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., Savović, J., Schulz, K. F., Weeks, L., & Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *British Medical Journal*, 343.

Higgins, J., & Green, S. M. (2011). *Cochrane Handbook for Systematic Reviews of Interventions* J. Higgins & S. M. Green (Eds.), Retrieved from <http://handbook.cochrane.org>

Higginson, I. (2012). Emergency department crowding. *Emergency Medicine Journal*, 29(6), 437-443.

Hine, M. J. K., Farion, W., Michalowski, S., & Wilk, S. (2009). Decision Making By Emergency Room Physicians And Residents: Implications for the Design of Clinical Decision Support Systems. *International Journal of Healthcare Information Systems and Informatics*, 4(2), 17-35.

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S. E., Dixon-Woods, M., McCulloch, P., Wyatt, J. C., Chan, A. W., & Michie, S. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal*, 348.

Holroyd, B., Bullard, M., Graham, T., & Rowe, B. (2007). Decision support technology in knowledge translation. [Research Support, Non-U.S. Gov't]. *Academic Emergency Medicine*, 14(11), 942-948. doi: 10.1197/j.aem.2007.06.023

- Honey, P., & Mumford, A. (1982). *Manual of Learning Styles*. Oxford: Peter Honey publications.
- House of Commons. Health Select Committee. (2008). Modernising Medical Careers. Retrieved from <http://www.publications.parliament.uk/pa/cm200708/cmselect/cmhealth/25/25i.pdf>
- HSCIC. (2011). Accident and Emergency Attendances in England 2009-2010 Retrieved 2 October, 2012, from <http://www.hscic.gov.uk/hes>
- HSCIC. (2014). Accident and Emergency Department Type Retrieved 12 January, 2014, from [http://www.datadictionary.nhs.uk/data\\_dictionary/attributes/a/acc/accident\\_and\\_emergency\\_department\\_type\\_de.asp?shownav=1](http://www.datadictionary.nhs.uk/data_dictionary/attributes/a/acc/accident_and_emergency_department_type_de.asp?shownav=1)
- HSCIC. (n.d.). Find data Retrieved 24 March, 2014, from <http://www.hscic.gov.uk/searchcatalogue?q=A%26E&area=&size=10&sort=Relevance&topics=0%2FHospital+care-top>
- Hughes, G. (2006). Triage; evolution or extinction. *Emergency Medicine Journal*, 23(2), 88-88.
- Hunt, D., Haynes, B., Hanna, S., & Smith, K. (1998). Effects of Computer-Based Clinical Decision Support systems on Physician Performance and Patient Outcomes. *The Journal of the American Medical Association*, 280(15), 1339-1346.
- Hunt, M. T., & Glucksmann, M. E. (1991). A review of 7years of complaints in an inner-city accident and emergency department. [10.1136/emj.8.1.17]. *Archives of Emergency Medicine*, 8, 17-23.
- Hwang, U., Harris, B., Morrison, R. S., & Richardson, L. D. (2006). The Effect of Emergency Department Crowding Factors on Pain Management. *Annals of Emergency Medicine*, 48(4, Supplement), 117. doi: <http://dx.doi.org/10.1016/j.annemergmed.2006.07.858>
- Institute of Medicine. (2000). *To Err is Human: Building a safer health care system*. Washington DC: National Academies Press.
- International Federation for Emergency Medicine. (2012). Framework for Quality and Safety in the Emergency Department. Retrieved from <http://www.ifem.cc/Resources/PoliciesandGuidelines.aspx>
- Jadav, M. A. R., Lloyd, G., McLauchlan, C., & Hayes, C. (2009). Routine pain scoring does not improve analgesia provision for children in the emergency department. *Emergency Medicine Journal*, 26(10), 695-697. doi: 10.1136/emj.2008.060384
- Janta, H., Lugosi, P., & Brown, L. (2014). Coping with Loneliness: A netographic study

of doctoral students. *Journal of Further and Higher Education*, 38(4), 553-571. doi: 10.1080/0309877X.2012.726972

Jarman, H. (2009). Sharing expertise - using clinical nursing rounds to improve UK emergency nursing practice. *Australasian Emergency Nursing*, 12(3), 73-77.

Jones, B., Jones, J., Stoddard, G., Vines, C. G., Jepson, A., Ferraro, J. P., Post, H., Briggs, B., Griffin, P., Kumar, N., Allen, T. L., Haug, P., J., & Dean, N. C. (2013). *Impact of electronic decision support tool on outcomes for emergency department patients with pneumonia*. Paper presented at the European Respiratory Society Annual Congress, Barcelona.

Jones, P., & Schimanski, K. (2010). The four hour target to reduce emergency department 'waiting time': a systematic review of clinical outcomes. *Emergency Medicine Australasia* 22, 391-398.

Kahneman, D. (2011). *Thinking, Fast and Slow*. London: Penguin.

Kaplan, B. (2001). Evaluating informatics applications - clinical decision support systems literature review *International Journal of Medical Informatics*, 64, 15-37.

Kawamoto, K., Houlihan, C. A., Balas, E. A., & Lobach, D. F. (2005). Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. [10.1136/bmj.38398.500764.8F]. *British Medical Journal*, 330(7494), 765.

Kearns, H., Gardiner, M., Marshall, K., & Banytis, F. (2009). *The PhD Experience: What they didn't tell you at induction*. Adelaide: Flinders University - Staff Development and Training Unit.

Kelman, S., & Friedman, J. N. (2009). Performance improvement and performance dysfunction: an empirical examination of distortionary impacts of the emergency room wait-time target in the English National Health Service. *Journal of Public Administration and Research Theory*, 19, 917-946.

Keogh, B. (2013a). *Review into the quality of care and treatment provided by 14 hospital trusts in England: overview report*. London: DH Retrieved from <http://www.nhs.uk/NHSEngland/bruce-keogh-review/Documents/outcomes/keogh-review-final-report.pdf>

Keogh, K. (2013b). One-off £500 million not enough to solve A&E crisis, RCN warns. *Nursing Standard*, 28(3), 11.

Kings Fund. (2013). Are accident and emergency attendances increasing? Retrieved 22 October, 2013, from <http://www.kingsfund.org.uk/blog/2013/04/are-accident-and-emergency-attendances-increasing>

Kings Fund. (n.d.). Have targets improved NHS performance Retrieved 12 February 2012, from

<http://www.kingsfund.org.uk/projects/general-election-2010/key-election-questions/performance-targets>

Kirk, R. C., Li-Meng Goh, D., Packia, J., Min Kam, H., & Ong, B. K. C. (2005). Computer calculated dose in paediatric prescribing. *Drug Safety: An International Journal Of Medical Toxicology And Drug Experience*, 28(9), 817-824.

Kondrat, M. (1999). Self-Aware: Professional Self-Awareness from a Critical theory Perspective. *Social Sceince Review*, 73(4), 451-477.

Kulstad, E. B., Sikka, R., Sweis, R. T., Kelley, K. M., & Rzechula, K. H. (2010). ED overcrowding is associated with an increased frequency of medication errors. *The American Journal of Emergency Medicine*, 28(3), 304-309. doi: 10.1016/j.ajem.2008.12.014

Kwok, R., Dinh, M., Dinh, D., & Chu, M. (2009). Improving adherence to asthma clinical guidelines and discharge documentation from emergency departments: implementation of a dynamic and integrated electronic decision support system. *Emergency Medicine Australasia*, 21(1), 31-37. doi: 10.1111/j.1742-6723.2008.01149.x

Landis, J. R., & Koch, G. H. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33, 159-174.

Lau, F., Kuziemy, C., Price, M., & Gardner, J. (2010). A review on systematic reviews of health information system studies. *Journal of the American Medical Informatics Association*, 17(6), 637-645.

Lee, G., Smith, S., & Jennings, N. (2008). Low acuity abdominal pain in the Emergency Department: Still a long wait. *International Emergency Nursing*, 16(2), 94-100. doi: 10.1016/j.ienj.2008.01.006

Lee, N. J. (2009). *Achieving your professional doctorate. A handbook*. Maidenhead: Open University Press.

Letham, K., & Gray, A. (2012). The four-hour target in the NHS emergency departments: a critical comment. *Emergencias*, 24, 69-72.

Lilford, R. J., Brown, C. A., & Nicholl, J. (2007). Use of process measures to monitor the quality of clinical practice. [10.1136/bmj.39317.641296.AD]. *British Medical Journal*, 335, 648-650.

Lim, C., Bawden, J., Wing, A., Villa-Roel, C., Meurer, D. P., Bullard, M. J., & Rowe, B. H. (2012). Febrile neutropenia in EDs: the role of an electronic clinical practice guideline. *The American Journal of Emergency Medicine*, 30(1), 5-11.e15. doi: <http://dx.doi.org/10.1016/j.ajem.2010.08.011>

Lindley-Jones, M., & Finlayson, B. J. (2000). Triage nurse requested x rays, Are they worthwhile? *Journal of Accident & Emergency Medicine*, 17(2), 103-107.



- Liu, J., & Wyatt, J., C. (2011). The case for randomized controlled trials to assess the impact of clinical information systems. *Journal of the American Medical Informatics Association*, 18(2), 173-180.
- Liu, J., Wyatt, J., Deeks, J., Clamp, S., Keen, J., Verde, P., Ohmann, C., Wellwood, J., Dawes, M., & Itman, D. (2006). Systematic Review of clinical decision tools for acute abdominal pain. *Health Technology Assessment*, 10(41).
- Livingston, P., Craike, M., & Considine, J. (2011). Unplanned presentations to emergency departments due to chemotherapy induced complications: Opportunities for improving service delivery. *Australasian Emergency Nursing*, 14(2), 62-68. doi: 10.1016/j.aenj.2011.03.005
- Lobach, D., Sanders, G., Bright, T., Wong, A., Dhurjati, R., Bristow, E., Bastian, L., Coeytaux, R., Samsa, G., Hasselblad, V., Williams, J. W., Wing, L., Musty, M., & Kendrick, A. (2012). Enabling Health Care Decisionmaking Through Clinical Decision Support and Knowledge Management. Evidence Report No 203 Retrieved 17 March, 2014, from <http://www.ahrq.gov/research/findings/evidence-based-reports/er203-abstract.html>
- Lord, M. (2002). Making a difference: the implications for nurse education. *Nursing Times*, 98(20), 38-40.
- Mackway-Jones, K., Marsden, J., & Windle, J. (Eds.). (2006). *Emergency Triage* (2nd ed.). London: Blackwell.
- Main, C., Moxham, T., Wyatt, J. C., Kay, J., Anderson, R., & Stein, K. (2010). Computerised decision support systems in order communication for diagnostic, screening or monitoring test ordering: systematic reviews of the effects and cost-effectiveness of systems. *Health Technology Assessment (Winchester, England)*, 14(48), 1-227. doi: 10.3310/hta14480
- Malfroy, J. (2004). Conceptualisation of a Professional Doctorate Program: Focusing on Practice and Change. *The Australian Educational Researcher*, 31(2), 63-79.
- Manchester Evening News. (2013). Health non-emergency helpline across Greater Manchester in doubt as NHS Direct pulls out Retrieved 3 November, 2013, from <http://www.manchestereveningnews.co.uk/news/health/health-111-non-emergency-helpline-across-5382561>
- Manley, K., Webster, J., Hale, N., Hayes, N., & Minardi, H. (2008). Leadership role of consultant nurses working with older people: a co-operative enquiry. *Journal of Nursing Management*, 16(2), 147-158.
- McGlynn, E. A., Asch, S. M., Adams, J., Keeseey, J., Hicks, J., DeCristofaro, A., & Kerr, E. A. (2003). The Quality of Health Care Delivered to Adults in the United States. *New England Journal of Medicine*, 348(26), 2635-2645. doi: 10.1056/NEJMsa022615
- McNeill, G., Brahmbhatt, D., Prevost, A., & Trepte, N. J. (2009). What is the effect



of a consultant presence in an acute medical unit? *Clinical Medicine*, 9(3), 214-218.

McWay, D. (2002). *Legal Aspects of Health Information Management*. New York: Thomson Delmar Learning.

Melnick, E. R., Genes, N. G., Chawla, N. K., Akerman, M., Baumlin, K. M., & Jagoda, A. (2010). Knowledge translation of the American College of Emergency Physicians' clinical policy on syncope using computerized clinical decision support. *International Journal Of Emergency Medicine*, 3(2), 97-104. doi: 10.1007/s12245-010-0168-x

Michielutte, R., Shelton B., Paskett, E., Tatum, C., M., , & Velez, R. (2000). Use of interrupted time series to evaluate a cancer screening programme. *Health Education research*, 15(5), 6145-6623.

Mohr, N. M., Faine, B., Harland, K., Porter, B., & Draus, K. (2013). Computerized decision-support decreases vancomycin underdosing errors with modest effect on dosing accuracy in critically ill patients in the emergency department. *Annals of Emergency Medicine*, 62(4 SUPPL. 1), S133-S134.

Mort, D., Lansdown, M., Smith, N., Protopapa, K., & Mason, M. (2008). *For better, for worse?. A review of the care of patients who died with 30 days of receiving SACT*. London: National Confidential Enquiry into Patient Outcome and Death Retrieved from [http://www.ncepod.org.uk/2008report3/Downloads/SACT\\_report.pdf](http://www.ncepod.org.uk/2008report3/Downloads/SACT_report.pdf).

Murray, S. L., Crouch, R., & Ainsworth-Smith, M. (2012). Quality of the handover of patient care: A comparison of Pre-Hospital and Emergency Department notes. *International Emergency Nursing*, 20(1), 24-27. doi: 10.1016/j.ienj.2010.09.004

Murray, S. L., Crouch, R., Pope, C., Lattimer, V., Thompson, F., Deakin, C., & Ainsworth-Smith, M. (2011). Improving the quality of ambulance crew hand-overs: a qualitative study of knowledge transfer in emergency care teams. *Emergency Medicine Journal*, 28(3), e1-e1.

National Advisory Group on the Safety of Patients in England. (2013). *A promise to learn - a commitment to act: improving the safety of patients in England*. Retrieved from [https://http://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/226703/Berwick\\_Report.pdf](https://http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226703/Berwick_Report.pdf).

National Audit Office. (2006). *The National Programme for IT in the NHS*. London: NAO.

National Chemotherapy Advisory Group. (2009). Chemotherapy Services in England. Ensuring quality and safety. Retrieved from [http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod\\_consum\\_dh/groups/dh\\_digitalassets/documents/digitalasset/dh\\_104501.pdf](http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_104501.pdf)

National Institute for Health Care Excellence. (2012). Neutropenic sepsis: prevention and management of neutropenic sepsis on cancer patient Retrieved 1 August,

2013, from <http://www.nice.org.uk/guidance/CG151>

National Institute for Health Care Excellence. (2014). Triage, assessment, investigation and early management of head injury in infants, children and adults Retrieved 1 March 2014, from <http://www.nice.org.uk/CG056>

National Resource Centre for Academic Detailing. (2014). Academic Detailing Retrieved 22 March, 2014, from <http://www.narcad.org>

Nelson, J., Smith, B., Jared, J., & Younger, J. (2010). Real-time data mining and caregiver decision support for ED patients with severe sepsis. *Shock*, 33.

Nelson, J., Smith, B. L., Jared, J. D., & Younger, J. G. (2011). Prospective Trial of Real-Time Electronic Surveillance to Expedite Early Care of Severe Sepsis. *Annals of Emergency Medicine*, 57(5), 500-504.

Newell, A., & Simon, H. A. (1972). *Human Problem Solving*. New Jersey: Prentice Hall.

NHS Choices. (2013). Emergency and Urgent Care Services Retrieved 2 October, 2013, from <http://www.nhs.uk/NHSEngland/AboutNHSservices/Emergencyandurgentcareservices/Pages/NHS-111.aspx>

NHS Direct. (n.d.). What is NHS Direct Retrieved 24 October, 2013, from <http://www.nhsdirect.nhs.uk/About/WhatIsNHSDirect>

NHS Employers. (n.d.). European Working Time Directive Retrieved 21 June, 2014, from <http://www.nhsemployers.org/your-workforce/need-to-know/european-working-time-directive>

NHS England. (2014a). High quality care for all, now and future generations. About us Retrieved 2 March 2014, from <http://www.england.nhs.uk/about/>

NHS England. (2014b). High quality care for all, now and future generations. What do we mean by high quality care? Retrieved 2 March, 2014, from <http://www.england.nhs.uk/about/imp-our-mission/high-quality-care/>

NHS Executive. (1999). *Nurse, midwife and health visitor consultants*. Health Service Circular 1999/217. NHS Executive. Leeds.

NHS Improving Quality. (n.d.). NHS Improving Quality (NHS IQ) Retrieved 2 April 2013, from <http://www.nhsiq.nhs.uk/about-us.aspx>

NHS Institute for Innovation and Improvement. (n.d.). QIPP: Establishing the evidence Retrieved 13 October, 2013, from [http://www.institute.nhs.uk/establishing\\_evidence/establishing\\_evidence/background.html](http://www.institute.nhs.uk/establishing_evidence/establishing_evidence/background.html)

Niazkhani, Z., Pirnejad, H., Berg, M., & computerized provider order entry

Aarts, J. (2009). The impact of systems on inpatient clinical workflow: a

literature review. *Journal Of The American Medical Informatics Association*, 16(4), 539-549. doi: 10.1197/jamia.M2419

Niemi, K., Geary, S., Quinn, B., Larrabee, M., & Brown, K. (2009). Implementation and evaluation of electronic clinical decision support for compliance with pneumonia and heart failure quality indicators. *American Journal of Health-System Pharmacy*, 66(4), 389-397.

Nieuwlaat, R., Connolly, S. J., Mackay, J. A., Weise-Kelly, L., Navarro, T., Wilczynski, N. L., & Brian Haynes, R. (2011). Computerized clinical decision support systems for therapeutic drug monitoring and dosing: A decision-maker-researcher partnership systematic review. *Implementation Science*, 6(1), 90. doi: 10.1186/1748-5908-6-90

Noon, A. (2014). The cognitive processes underpinning clinical decision in triage assessment: a theoretical conundrum? *International Emergency Nursing*, 22(1), 40-46. doi: 10.1016/j.ienj.2013.01.003

NRES Ethics Consultation E-Group. (2007). Differentiating audit, service evaluation and research. Retrieved from <http://www.hra.nhs.uk/documents/2013/10/differentiating-audit-service-evaluation-and-research-version-1-1.pdf>

Nursing and Midwifery Council. (2010). Nursing now and in the future Retrieved 22 October, 2013, from <http://www.nmc-uk.org/Get-involved/Consultations/Past-consultations/By-year/Pre-registration-nursing-education-Phase-2/Nurse-education-Now-and-in-the-future/>

O'Brien, D., Williams, A., Blondell, K., & Jelinek, G. A. (2006). Impact of streaming "fast track" emergency department patients. *Australian Health Review*, 30(4), 525-532.

O'Cathain, A., Sampson, F. C., Munro, J. F., Thomas, K. J., & Nicholl, J. P. (2004). Nurses' views of using computerized decision support software in NHS Direct. *Journal Of Advanced Nursing*, 45(3), 280-286.

O'Dowd, A. (2013, 23 October 2013). Locums make up a fifth of doctors in emergency units at weekends Retrieved 3 March, 2014, from <http://www.publications.parliament.uk/pa/cm201314/cmselect/cmhealth/171/17108.htm - n82>

Olofsson, P., Gellerstedt, M., & Carlstrom, E. D. (2009). Manchester Triage in Sweden - Interrater reliability and accuracy. *International Emergency Nursing*, 17(3), 143-148.

Øvretveit, J., Scott, T., Rundall, T. G., Shortell, S. M., & Brommels, M. (2007). Improving quality through effective implementation of information technology in healthcare. *International Journal for Quality in Health Care*, 19(5), 259-266.

Paiva, L., Providencia, R., Faustino, A., Barra, S., Botelho, A., & Leitao-Marques, A. M. (2012). Manchester triage in acute pulmonary embolism: can it unmask the

grand impersonator? *Emergency Medicine Journal*, 29(12), e6-e6.

Pallant, J. (2007). *SPSS Survival Manual*. Maidenhead: McGraw Hill.

Parenti, N., Reggiani, M., Iannone, P., & Dowding, D. (2014). A Systematic Review on the validity and reliability of the Manchester Triage System. *International Journal of Nursing Studies*, 51, 1062-1069. doi: <http://dx.doi.org/10.1016/j.ijnurstu.2014.01.013>

Parker, B. T., & Marco, C. (2014). Emergency Department Length of Stay: accuracy of Patient Estimates. [10.5811/westjem.2013.9.15816]. *Western Journal of Emergency Medicine*, 15, 170-175.

Parliamentary Health Service Ombudsman. (2013). *Time to Act: Severe sepsis: rapid diagnosis and treatment saves lives*. London: PHSO Retrieved from [http://www.ombudsman.org.uk/\\_data/assets/pdf\\_file/0004/22666/FINAL\\_Sepsis\\_Report\\_web.pdf](http://www.ombudsman.org.uk/_data/assets/pdf_file/0004/22666/FINAL_Sepsis_Report_web.pdf).

Patel, V., Gutnik, L., Karlin, D., & Pusic, M. (2008). Calibrating urgency: triage decision-making in a pediatric emergency department. *Advances in Health Sciences Education*, 13(4), 503-520. doi: 10.1007/s10459-007-9062-6

Paul, R., & Elder, L. (2002). *Critical Thinking. tools for Taking Charge of Your Personal and Professional Life*. New Jersey: Prentice Hall.

Payne, T. H. (2000). Computer Decision Support Systems. *Chest*, 118(2), 47S-52. doi: 10.1378/chest.118.2\_suppl.47S

Peat, J., & Barton, B. (2005). *Medical statistics: a guide to data analysis and critical appraisal*. London: Wiley Blackwell.

Pickier Institute. (2012). Accident and Emergency Department Survey Retrieved 11 November, 2012, from <http://www.pickereurope.org/a-and-e2012.html>

Pines, J., Iyer, S., Disbot, M., Hollander, J., Shofer, F., & Datner, E. (2008). The effect of emergency department crowding on patient satisfaction for admitted patients. *Academic Emergency Medicine*, 15, 825-831.

Pines, J. M., & Hollander, J. E. (2008). Emergency Department Crowding Is Associated With Poor Care for Patients With Severe Pain. *Annals of Emergency Medicine*, 51(1), 1-5. doi: 10.1016/j.annemergmed.2007.07.008

Pines, J. M., Localio, A. R., Hollander, J. E., Baxt, W. G., Lee, H., Phillips, C., & Metlay, J. P. (2007). The Impact of Emergency Department Crowding Measures on Time to Antibiotics for Patients With Community-Acquired Pneumonia. *Annals of Emergency Medicine*, 50(5), 510-516. doi: 10.1016/j.annemergmed.2007.07.021

Polit, D., & Beck, T., C. (2008). *Nursing Research. Generating and Assessing Evidence*

of *Nursing Practice* (8th ed.). Philadelphia: Lippincott, Williams & Wilkins.

Providência, R., Gomes, P., Barra, S., Silva, J., Seca, L., Antunes, A., Pais, J., Mota, P., & Leitão-Marques, A. (2011). Importance of Manchester Triage in acute myocardial infarction: impact on prognosis. *Emergency Medicine Journal*, 28(3), 212-216.

Public Accounts Committee. (2009). *The National Programme for IT in the NHS: Progress since 2006*. London: The Stationary Office Retrieved from <http://www.publications.parliament.uk/pa/cm200809/cmselect/cmpubacc/153/153.pdf>.

Public Accounts Committee. (2011). The National Programme for IT in the NHS: an update on the delivery of the detailed care records system Retrieved 2 March, 2014, from <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmpubacc/1070/107002.htm>

Punch, K. (2006). *Developing Effective Research Proposals* (2nd ed.). London: Sage.

Raja, A. S., Ip, I. K., Prevedello, L. M., Sodickson, A. D., Farkas, C., Zane, R. D., Hanson, R., Goldhaber, S. Z., Gill, R. R., & Khorasani, R. (2012). Effect of computerized clinical decision support on the use and yield of CT pulmonary angiography in the emergency department. *Radiology*, 262(2), 468-474. doi: 10.1148/radiol.11110951

Ramsay, C., Matowe, L., Grilli, R., Grimshaw, J., & Thomas, R. (2003). Interrupted Times Series Designs in Health Technology Assessment: Lessons from two systematic reviews of behaviour change strategies. *International Journal of Technology Assessment in Health Care*, 19(4), 613-623.

Randolph, A. G., Haynes, B., Wyatt, J. C., Cook, D., J., & Guyatt, G. H. (1999). Users' Guides to the Medical Literature: XVIII. How to Use an Article Evaluating the Clinical Impact of a Computer-Based Clinical Decision Support System. *The Journal of the American Medical Association*, 282(1), 67-74. doi: 10.1001/jama.282.1.67

Reckmann, M. H., Westbrook, J. I., Koh, Y., Lo, C., & Day, R. O. (2009). Does computerized provider order entry reduce prescribing errors for hospital inpatients? A systematic review. *Journal Of The American Medical Informatics Association*, 16(5), 613-623. doi: 10.1197/jamia.M3050

Redfern, E., Brown, R., & Vincent, C. A. (2009). Improving communication in the emergency department. *Emergency Medicine Journal*, 26(9), 658-661.

Restuccia, J., Cohen, A., Horwitt, J., & Shwartz, M. (2012). Hospital implementation of health information technology and quality of care: are they related? *BMC medical informatics and decision making*, 12(1), 109.

Riso, D., & Hudson, R. (1999). *The Wisdom of the Enneagram. the complete Guide to Psychological and Spiritual Growth for the Nine Personality Types*. New York: Bantam

## Books.

Robertson-Steel, I. (2006). Evolution of triage systems. *Emergency Medicine Journal*, 23(2), 154-155.

Robson, L., Shannon, H., Goldenhar, L., & Hale, A. (2001). Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries: How to Show Whether a Safety Intervention Really Works Retrieved 17 April, 2013, from <http://www.iwh.on.ca/evaluating-safety-programs>

Roshanov, P., Fernandes, N., Wilczynski, J., Hemens, B., You, J., Handler, S., Nieuwlaat, R., Souza, N., Beyene, J., Spall, H., Van Garg, A., & Haynes, R. (2013). Features of effective computerised clinical decision support systems: meta-regression of 162 randomised trials. *British Medical Journal*, 346.

Roshanov, P., Misra, S., Gertein, H., Garg, A., Sebaldt, R., Mackay, J., Weise-Kelly, Navarro, T., Wilczynski, N., & Haynes, B. (2011a). Computerised clinical decision support systems for chronic disease management: A decision-maker-researcher partnership systematic review. *Implementation Science*, 6(92), 1-16.

Roshanov, P., You, J., Dhaliwal, J., Koff, D., Mackay, J., Weise-Kelly, L., Navarro, T., Wilczynski, N., & Brian Haynes, R. (2011b). Can computerized clinical decision support systems improve practitioners' diagnostic test ordering behavior? A decision-maker-researcher partnership systematic review. *Implementation Science*, 6(1), 88. doi: 10.1186/1748-5908-6-88

Roukema, J., Steyerberg, E. W., van der Lei, J., & Moll, H. A. (2008). Randomized trial of a clinical decision support system: impact on the management of children with fever without apparent source. *Journal of the American Medical Informatics Association*, 15(1), 107-113.

Roukema, J., Steyerberg, E. W., van Meurs, A., Ruige, M., van der Lei, J., & Moll, H. A. (2006). Validity of the Manchester Triage System in paediatric emergency care. *Emergency Medicine Journal*, 23(12), 906-910.

Roy, P.-M., Durieux, P., Gillaizeau, F., Legall, C., Armand-Perroux, A., Martino, L., Hachelaf, M., Dubart, A.-E., Schmidt, J., Cristiano, M., Chretien, J.-M., Perrier, A., & Meyer, G. (2009). A computerized handheld decision-support system to improve pulmonary embolism diagnosis: a randomized trial. *Annals of Internal Medicine*, 151(10), 677-686. doi: 10.7326/0003-4819-151-10-200911170-00003

Royal College of Surgeons. (2010). NHS locum doctor costs in NHS Trusts in England. Results of a study from the Royal College of Surgeons England Retrieved 22 October, 2013, from <http://www.rcseng.ac.uk/publications/docs/locum-doctor-costs-in-nhs-trusts-in-england>

Royal College of Surgeons. (n.d.). NHS locum doctor spend spirals as new EU regulations bite Retrieved 22 October, 2013, from

<http://www.rcseng.ac.uk/media/medianews/nhs-locum-doctor-spend-spirals-as-eu-regulations-bite>

Rund, D., & Rausch, T. S. (1981). *Triage*. St Louis: CV Mosby.

Ryan, S., Hassell, A., Thwaites, C., Manley, K., & Home, D. (2006). Exploring the perceived role and impact of the nurse consultant. *Musculoskeletal Care*, 4(3), 167-173.

Sahota, N., Lloyd, R., Ramakrishna, A., Mackay, J., Prorok, J. A., Weise-Kelly, L., Navarro, T., Wilczynski, N. L., & Haynes, R. B. (2011). Computerised clinical decision support systems for acute care management: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. *Implementation Science*, 6(91).

Saks, M., & Allsop, J. (Eds.). (2007). *Researching Health. Qualitative, Quantitative and Mixed methods*. London: Sage.

Salisbury, C. (2003). Do NHS walk-in centres in England provide a model of integrated care? *International Journal of Integrated Care*, 3(18), 1-7.

Sanders, D. L., & Aronsky, D. (2006). Biomedical informatics applications for asthma care: a systematic review. *Journal of the American Medical Informatics Association*, 13(4), 418-427.

Sard, B. E., Walsh, K. E., Doros, G., Hannon, M., Moschetti, W., & Bauchner, H. (2008). Retrospective evaluation of a computerized physician order entry adaptation to prevent prescribing errors in a pediatric emergency department. *Pediatrics*, 122(4), 782-787.

Sbaih, L. (1998). Initial assessment: gaining impressions and "normal cases". *Accident and Emergency Nursing*, 6(2), 70-74. doi: [http://dx.doi.org/10.1016/S0965-2302\(98\)90002-9](http://dx.doi.org/10.1016/S0965-2302(98)90002-9)

Schriger, D. L., Baraff, L. J., Buller, K., Shendrikar, M. A., Nagda, S., Lin, E., J., Mikulich, V., J., & Cretin, S. (2000). Implementation of Clinical Guidelines via a Computer Charting System: Effect on the Care of Febrile Children Less than Three Years of Age. *Journal of the American Medical Informatics Association*, 7(2), 186-195.

Schriger, D. L., Baraff, L. J., Rogers, W. H., & Cretin, S. (1997). Implementation of clinical guidelines using a computer charting system. Effect on the initial care of health care workers exposed to body fluids. *The Journal of the American Medical Association*, 278(19), 1585-1590.

Schull, M. J., Vermeulen, M., Slaughter, G., Morrison, L., & Daly, P. (2004). Emergency department crowding and thrombolysis delays in acute myocardial infarction. *Annals of Emergency Medicine*, 44(6), 577-585. doi: 10.1016/j.annemergmed.2004.05.004



Scott, I. (2009). What are the most effective strategies for improving quality and safety of health care? *Internal Medicine Journal*, 39(6), 389-400. doi: 10.1111/j.1445-5994.2008.01798.x

Shcherbatykh, I., Holbrook, A., Thabane, L., & Dolovich, L. (2008). Methodologic Issues in Health Informatics Trials: The Complexities of Complex Interventions. *Journal of the American Medical Informatics Association*, 15(5), 575-580.

Sheldon, T., Cullum, N., Dawson, D., Lankshear, A., Lowson, K., Watt, I., West, P., Wright, D., & Wright, J. (2004). What's the evidence that NICE guidance has been implemented? Results from a national evaluation using time series analysis, audit of patients' notes, and interviews. *British Medical Journal*, 329(7473), 999.

Shiffman, R., Liaw, Y., Brandt, C. A., Corb, G. J. . (1999). Computer-based Guideline Implementation Systems. *Journal of the American Medical Informatics Association*, 6, 104-114.

Singer, A., Thode, H., Viccellio, P., & Pines, J. M. (2011). The Association Between Length of Emergency Department Boarding and Mortality. *Academic Emergency Medicine*, 18(12), 1324-1329. doi: 10.1111/j.1553-2712.2011.01236.x

Siriwardena, A. (2007). Experimental Methods in Health Research. In M. Saks & J. Allsop (Eds.), *Researching Health. Qualitative, Quantitative and Mixed Methods*. Los Angeles: Sage.

Smith, A. (2013a). Using a theory to understand triage decision making. *International Emergency Nursing*, 21(2), 113-117. doi: 10.1016/j.ienj.2012.03.003

Smith, A., & Cone, K. (2010). Triage decision-making skills: a necessity for all nurses. *Journal For Nurses In Staff Development*, 26(1), E14-E19. doi: 10.1097/NND.0b013e3181bec1e6

Smith, M., & Feied, C. (1999). The Emergency Department as a Complex System. Retrieved from <http://necsi.edu/projects/yaneer/emergencydeptcx.pdf>

Smith, N. J. (2013b). Professional doctorates and nursing practice contribution: a systematic literature search and descriptive synthesis. *Journal of Nursing Management*, 21, 314-326.

Smith, S. (2012). QIPP Programme (Quality, Innovation, Productivity and Prevention) Retrieved 23 October, 2013, from <http://ukpolicymatters.thelancet.com/qipp-programme-quality-innovation-productivity-and-prevention/>

Souza, N. M., Sebaldt, R. J., Mackay, J. A., Prorok, J. C., Weise-Kelly, L., Navarro, T., Wilczynski, N. L., & Haynes, R. B. (2011). Computerized clinical decision support systems for primary preventive care: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. *Implementation Science*, 6(1), 87. doi: 10.1186/1748-5908-6-87



Standing, M. (2008). Clinical judgement and decision-making in nursing – nine modes of practice in a revised cognitive continuum. *Journal Of Advanced Nursing*, 62(1), 124-134. doi: 10.1111/j.1365-2648.2007.04583.x

Storm-Versloot, M. N., Ubbink, D. T., Chin a Choi, V., & Luitse, J. S. K. (2009). Observer agreement of the Manchester Triage System and the Emergency Severity Index: a simulation study. *Emergency Medicine Journal*, 26(8), 556-560.

Sujan, M. A., Chessum, P., Rudd, M., Fitton, L., Inada-Kim, M., Spurgeon, P., & Cooke, M. W. (2013). Emergency Care Handover (ECHO study) across care boundaries: the need for joint decision making and consideration of psychosocial history. *Emergency Medicine Journal*, (0), 1-7. Retrieved from <http://emj.bmj.com/content/early/2013/09/11/ememed-2013-202977.abstract>

Talbot, R., & Bleetman, A. (2007). Retention of information by emergency department staff at ambulance handover: do standardised approaches work? *Emergency Medicine Journal*, 24(8), 539-542.

Talmon, J., Ammenwerth, E., Brender, J., de Keizer, N., Nykänen, P., & Rigby, M. (2009). STARE-HI Statement on reporting of evaluation studies in Health Informatics. *International Journal of Medical Informatics*, 78(1), 1-9.

Tanner, C. A., Padrick, K. P., Westfall, U. E., & Putzer, D. J. (1987). Diagnostc reasoning strategies of nurses and nursing students. *Nursing Research*, 36(6), 358-363.

Taylor, C., & Hicks, S. (2009). The practitioner-researcher: a critical and reflexive approach to professional practice. In N. Lee (Ed.), *Achieving your Professional Doctorate. A handbook*. Berkshire: McGraw-Hill.

Teanby, S. (2003). A literature review into pain assessment at triage in accident and emergency departments. *Accident And Emergency Nursing*, 11(1), 12-17. doi: [http://dx.doi.org/10.1016/S0965-2302\(02\)00132-7](http://dx.doi.org/10.1016/S0965-2302(02)00132-7)

Temple, J. (2010). *Time for Training. A Review of the impact of the European Working Time Directive on the quality of training*. London: Health Education England  
Retrieved from <http://hee.nhs.uk/wp-content/uploads/sites/321/2012/08/Time-for-training-report.pdf>.

Terrell, K. M., Perkins, A. J., Dexter, P. R., Hui, S. L., Callahan, C. M., & Miller, D. K. (2009). Computerized decision support to reduce potentially inappropriate prescribing to older emergency department patients: a randomized, controlled trial. *Journal of the American Geriatrics Society*, 57(8), 1388-1394. doi: 10.1111/j.1532-5415.2009.02352.x

Terrell, K. M., Perkins, A. J., Hui, S. L., Callahan, C. M., Dexter, P. R., & Miller, D. K. (2010). Computerized decision support for medication dosing in renal insufficiency: a randomized, controlled trial. *Annals of Emergency Medicine*, 56(6), 623-629. doi:

10.1016/j.annemergmed.2010.03.025

Thompson, C. (1999). A conceptual treadmill: the need for 'middle ground' in clinical decision making theory in nursing. *Journal Of Advanced Nursing*, 30(5), 1222-1229. doi: 10.1046/j.1365-2648.1999.01186.x

Thompson, C., & Dowding, D. (Eds.). (2001). *Clinical decision-making and judgement in nursing*. London: Churchill Livingstone.

Todd, K. H., Ducharme, J., Choiniere, M., Crandall, C. S., Fosnocht, D. E., Homel, P., & Tanabe, P. (2007). Pain in the Emergency Department: Results of the Pain and Emergency Medicine Initiative (PEMI) Multicenter Study. *The Journal of Pain*, 8(6), 460-466. doi: <http://dx.doi.org/10.1016/j.jpain.2006.12.005>

Trout, A., Magnusson, A. R., & Hedges, J. R. (2000). Patient satisfaction and the emergency department: what does the literature say? *Academic Emergency Medicine*, 7, 695-709.

Trzeciak, S., & Rivers, E. P. (2003). Emergency department overcrowding in the United States: an emerging threat to patient safety and public health. *Emergency Medicine Journal*, 20(5), 402-405.

UK Government. (2004). *National Health Service (General Medical Services Contracts) Regulations 2004*. (2004/291). Retrieved from [http://www.legislation.gov.uk/ukxi/2004/291/pdfs/ukxi\\_20040291\\_en.pdf](http://www.legislation.gov.uk/ukxi/2004/291/pdfs/ukxi_20040291_en.pdf).

United Kingdom Central Council for Nursing Midwifery and Health Visiting. (1986). Project 2000. A New Preparation for Practice. Retrieved from <http://www.nmc-uk.org/Documents/Archived Publications/UKCC Archived Publications/Project 2000 A New Preparation for Practice May 1986.PDF>

van der Wulp, I., Sturms, L., de Jong, A., Schot-Balfoort, M., Schrijvers, A., & van Stel, H. (2011). Pain assessments at triage with the Manchester triage system: a prospective observational study. *Emergency Medicine Journal*, 28(7), 585-589.

van der Wulp, I., van Baar, M. E., & Schrijvers, A. J. P. (2008). Reliability and validity of the Manchester Triage System in a general emergency department patient population in the Netherlands: results of a simulation study. *Emergency Medicine Journal*, 25(7), 431-434.

Viera, A. J., & Garrett, J. M. (2005). Understanding Interobserver Agreement: The Kappa Statistic. *Family Medicine*, 37(5), 360-363.

Vincent, C. (2010). *Patient Safety* (2nd ed.). London: Wiley-Blackwell.

Wanless, D. (2006). Securing good care for older people: Taking a long term view. London: Kings Fund.

Wears, R. L., Sutcliffe, K. M., Perry, S. J., & Vargherhoef, M. (2003). Understanding

Eisenberg, E. M., Murphy, A. G., & errors in the Emergency Department; A

convergent approach Retrieved 22 November, 2013, from <http://www.npsf.org/for-healthcare-professionals/programs/research-grants-program/past-grant-awards/2000-2001-grant-awards/>

Wears, R. L., Woloshynowych, M., Brown, R., & Vincent, C. A. (2010). Reflective analysis of safety research in the hospital accident & emergency departments. *Applied Ergonomics*, 41(5), 695-700. doi: 10.1016/j.apergo.2009.12.006

Weber, E. J., Mason, S., Freeman, J. V., & Coster, J. (2012). Implications of England's Four-Hour Target for Quality of Care and Resource Use in the Emergency Department. [10.1016/j.annemergmed.2012.08.009]. *Ann Emerg Med*, 60, 699-706.

Wellington, J., & Sikes, P. (2006). "A doctorate in a tight compartment": why do students choose a professional doctorate and what impact does it have on their personal and professional lives. *Studies in Higher Education*, 31(6), 723-734.

Westbrook, J. I., Coiera, E., Dunsmuir, W. T. M., Brown, B. M., Kelk, N., Paoloni, R., & Tran, C. (2010). The impact of interruptions on clinical task completion. *Quality and Safety in Health Care*, 19(4), 284-289.

White, A., L., Armstrong, P., A. R., & Thakore, S. (2010). Impact of senior clinical review on patient disposition from the emergency department. *Emergency Medicine Journal*, 27(4), 262-265.

Windle, J., & Mackway-Jones, K. (2003). Don't throw triage out with the bathwater. *Emergency Medicine Journal*, 20(2), 119-120.

Wolf, L. (2010). Does Your Staff Really "Get" Initial Patient Assessment? Assessing Competency in Triage Using Simulated Patient Encounters. *Journal of Emergency Nursing*, 36(4), 370-374. doi: <http://dx.doi.org/10.1016/j.jen.2010.04.016>

Woloshynowych, M., Davis, R., Brown, R., Wears, R., Vincent, C., & Lyons, M. (2006). Enhancing Safety in Accident and Emergency Care. Retrieved from <http://www.birmingham.ac.uk/Documents/college-mds/haps/projects/cfhep/psrp/finalreports/PS010AandEVincentetal2007.pdf>

Woodcock, T., Poots, A. J., & Bell, D. (2012). The impact of changing the 4hr emergency access standard on patient waiting times in emergency departments in England. *Emergency Medicine Journal*. doi: 10.1136/emmermed-2012-201175

Woolwich. (2000). Nurse Triage. In B. Dolan & L. Holt (Eds.), *Accident and Emergency: Theory into Practice* (pp. 475-484). Edinburgh: Baillière Tindall.

Worster, A., & Haines, T. (2004). Advanced statistics: Understanding Medical Record Review (MRR) Studies. *Academic Emergency Medicine*, 11(2), 187-192. doi: 10.1111/j.1553-2712.2004.tb01433.x

Wyatt, J. (1989). *Lessons from the field of ACORN, an expert system to advise on*

*chest pain*. Paper presented at the Sixth World Conference of Medical Informatics, China.

Wyatt, J., & Spiegelhalter, D. (1991). *Field trials of medical decision-aids: potential problems and solutions*. Paper presented at the Annual Symposium on Computer Application in Medical Care.

Wyatt, J. C. (2001). *Clinical Knowledge and Practice in the Information Age: a handbook for health professionals*. London: The Royal Society of Medicine Press Limited.